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# LECTURE NOTES

—ON—

# PHYSIOLOGY,

DELIVERED BEFORE THE

*January and April Classes*

OF THE

*American School of Osteopathy*

—BY—

DR. J. M. LITTLEJOHN.

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# INTRODUCTION.

In beginning the study of Physiology we must always remember that all Science is one and that there is unity in Science that specialization cannot dispense with.

When we abstract we tend to narrowness and bigotry. Science literally means knowledge, and it covers the whole field of knowledge but it also implies exactness of knowledge based upon observation, experiment and classification.

Observation and experimentation furnish the basal facts which are reasoned about and reduced to unity and system in the form of ideas; these ideas in turn forming the basis upon which science is systematically built up. Physiology is a part of science and a very essential part. Physiology literally means, from phusis and logos, reasoning about nature, in this case, limited to human nature, at least, in the field of human Physiology. Every form of life has a Physiology, so that Physiology really falls back upon Biology as the Primary Science. Biology is the Science of life in general. Physiology is the Science that reasons about the nature of life, its modes of activity and the actions of its organisms. In other words, it is the science of organized life. Morphology as distinguished from Physiology deals with the form and structure of living beings. Life, itself, from this standpoint, is that science of relations, physical, chemical and vital which gives us certain phenomena that we characterize as manifestations of vitality. This, of course, implies behind all phenomena the life principle.

Anatomy, Physiology and Pathology are the three great pillars upon which rests the Science of Medicine. The Science of Medicine is not limited to the prescription, and knowledge of Drugs or Physic; this is the degenerated idea of Medicine. The Science of Medicine deals with the preservation and prolongation of human life and with the curing of those abnormal conditions which tend to weaken or destroy life. Medicine in its history has followed several curative principles. Primitively associated with priestcraft, it consisted of certain ceremonial observances. Later it consisted of certain charms which the superstitious character of the people encouraged. To this day certain forms and incantations are believed to possess medicinal virtue. In the definition of the Science I have given, I think it is wide enough to cover Osteopathy, because I believe Osteopathy is a part of the Science of Medicine and Osteopathy should claim the word Medicine in its original sense, namely, that of healing. There are three great fields of knowledge in the Science of Medicine—Anatomy, Physiology and Pathology. Anatomy is the Science of organization or of the structure of the human system. Physiology is the science of organized life in its various functions. Pathology is the science which deals with abnormal conditions of human life. Symtomatology is the science which deals with results from the standpoint of Physiology and Pathology combined, with symptoms or signs of diseased conditions viewed from the standpoint of the expert physician who has a correct knowledge of Anatomy, Physiology and Pathology. To combat disease and consequently to prevent death we must have

a thorough knowledge of these sciences. These represent the normal con ditions and also the abnormal conditions. To understand and meet the unhealthful conditions we must know the healthful and health-giving conditions and functions. Physiology forms the middle science in this trinity of sciences and is a most essential study in the field of Medicine. But there is a wider field in which Physiology figures. Physiology has not only a bearing upon Medicine but also upon Psychology and through Psychology upon the whole field of education. Physiology explains and largely accounts for Psychological conditions; for true Psychology is founded on Physiology. The mental states and activities are of value only as the illustrations of Psychological relations and conditions. The psychic conditions of life are brought out not alone in the field of education, in adaptations to study but also in the study and diagnosis of mental diseases, and many of the nervous diseases. The Physiology of the brain, spinal cord and of the entire nervous system is at the foundation of every true theory of life, whether we take it in regard to physical life, in its preservation, prolongation and its treatment under diseased conditions or in regard to mental life and even the higher moral and spiritual life

A correct knowledge of Physiology applied in the field of Psychology has rendered obsolete older ideas and plans of education and has given rise to the modern natural school of education that has done so much to evolve didactic principles and plans for educating that is leading out and up the mind to the realms of knowledge rather than piling in the material into an already overcrowded mind. May we not look for the same reform in the field of medicine when Physiology is taught in all its bearings as it teaches the true functions of a differentiated human life consisting of a number of organs all of which are independent, and yet are united to form a single life. As we step into the higher field of Psycho physiology, we realize the fact that mind is the ascendant power and that in a healthy physical life nothing less than a healthy mind can secure that vigorous condition of body so much desired by all. We realize also that while we treat purely bodily diseases we must not overlook the fact that Psycho-pathy partly discloses mental diseases and mind conditions without the removal of which it is impossible to cure bodily diseases. This wide field we believe is opened before Osteopathy and we think that our claim is not too great when we say in beginning this course of Physiology that Physiology is the gateway by which this immense field is to be entered. In its bearings upon the human life with all its functions we constantly remember that it is our purpose in teaching Physiology, to lead your minds up to that high standard of knowledge regarding Physiology which will qualify you to become efficient operators in the field of Osteopathy.

# INDEX.


Alimentation..... 92
Diet.....92, 93, 94
Food selection..... 97
Food proportions..... 93, 99
Adipose tissue produced..... 98
FERMENTATION.....102
Protolytic.....103
Amyolytic.....103
Steatolytic.....103
Inversive.....103
Coagulating.....103
DIGESTION.....104
Mastication.....104
Insalivation.....107
Deglutition.....104, 107
Deglution stages.....108
Nervous Arrangement..109, 111
In Stomach.....110
Movements.....110
Influence on.....114
Periods of.....115
Conditions favoring.....117
In Small Intestine.....119
In Large Intestine.....124
ABSORPTION.....125, 136
During Digestion.....126
Blood.....126
Anabolism.....137
Animal Heat.....163
Astigmatism.....229
Asphyxia..... 82
Apnoea..... 81

Body, Chemical Composition of..... 20
Blood and Circulation..... 22
Alimentary canal..... 22
Lungs..... 22
Tissues Generally..... 23
Skin..... 23
Spleen..... 23
Gases of Blood..... 23
Circuit of Blood..... 23
Blood Pressure..... 31
BLOOD..... 36
Composition and Color..... 36
As a Tissue..... 38
Corpuscles.....19, 20, 36, 50
Coagulation..... 37
Absorption.....126
Body Tissue..... 40
Body Posture.....257
Bile, formation, composition, etc....120
Bladder.....162
Brain.....197, 198
Nerve Origin.....197
Cerebral Ganglia.....198
Optic Thalami.....199
Corpora Striata.....199
Cerebellum.....200
Cerebral Hemispheres.....200
Localization.....202
Disorder.....212
Treatment.....216

Cranial Nerves.....219
Origin.....197
Olfactory.....219
Optic.....220
Oculo-motor.....220
Trochlearis..... 220
Tri-facial.....220
Abducens.....221
Porto-dura.....222
Glosso-Pharyngeal.....222
Pneumogastric.....222
Spinal Accessory.....222
Hypoglossal.....223
Chemical Composition of Body..... 20
Circulation..... 23
Circulation of Heart..... 27

Contraction ..... 43
Physical Properties ..... 43
Chemical Properties ..... 44
Chemical Changes ..... 45
Electric Phenomena ..... 46
Negative Variation ..... 47
Tonicity ..... 48
Reproduction of Muscle ..... 48
Death of Muscle ..... 48
Unstriped ..... 48
Striated and Unstriated .....187
Mastication .....104, 107
Metabolism .....137
Micturition .....162
Memory .....210
Muscular Sense .....250
Medulla .....197
Nutrition .....20, 135
Nervous Tissue ..... 50
Physiology of ..... 50
Irritability .....52, 54
Terminals ..... 53
Nerve Fibers ..... 54
Physical Properties ..... 56
Chemical Properties ..... 56
Reproduction ..... 57
Reflex Action ..... 57
Inhibitory Action ..... 58
Fibers Classified ..... 59
Nerves of
Digestion .....109, 111
Respiration .....84, 91
Cranial (See Brain) .....216
Heart ..... 25
Depressor ..... 26
Blood Vessels ..... 33
Lymph Vessels .....129
Nervous System .....165, 203
Evolutionary Development .....171
Physiology of .....176
Nerve Cells .....176
Nerve Paths .....179
Nerve Fibers .....172
Cell Combination .....184
Diffusion of Impulses .....186
Relation with Striated and unstriated .....187
Distinction between Voluntary and Involuntary .....189
Pain Described .....190
Sensory Area .....191
Spinal Cord .....194
Sleep .....207
Old Age .....208
Memory .....210
Peripheral System .....218
Disease Treatment .....216
Organized and Unorganized Matter .. 19
Physiology Defined .....
Physiology Described ..... 19
Physiology, Human ..... 19
Proximate Principles of Body ..... 21
Pancreatic juice .....122
Pain Described .....190
Posture of Body .....257
Pancreas .....145
Pulse and Rate .....29, 30
Respiration ..... 60
Respiratory Apparatus ..... 61
Mechanism of ..... 63
Inspiration ..... 65
Expiration ..... 66
Periods ..... 68
Influence of Circulation ..... 70
Changes of the Air ..... 73
Changes in the Blood ..... 76
Through Tissues ..... 80
Apnoea ..... 81
Dysponea ..... 81
Asphyxia ..... 82
Inerevation .....84, 91
Centers ..... 84
Foetal Life ..... 92
Rhodopsin ..... 235
Reproduction ..... 167 to 269

Arteries ..... 28
Capillaries ..... 30
Venous ..... 31
Velocity ..... 33
Fœtal ..... 274
Influence of ..... 70
Chyle ..... 127
Color and Light ..... 236
Color Blindness ..... 237
Color, theory of ..... 237, 239

Diet ..... 92, 93, 94. 97, 99
Diseases of Nervous System ..... 216
Defects of Vision ..... 229, 237
Deglutition ..... 104, 107, 108
Digestion (see Alimentation.)
Dypsnœa ..... 81

Excretion ..... 151
Skin ..... 151
Sweat ..... 153
Sebaceous Glands ..... 154
Gaseous ..... 154
Kidneys ..... 155
Urine ..... 156
Urea ..... 157
Uric Acids ..... 159
Mechanism of ..... 159
Evolution ..... 259
Epiglottis ..... 62
Expiration ..... 66

Fœtal Life ..... 92
Food ..... 97, 99
Fœtal Blood Circulation ..... 274

Gastric Juice ..... 112
Glycogen, Glycogenesis ..... 139
Glycogen, where found ..... 143
Glands, Salivary ..... 145
Liver ..... 146
Pancreas ..... 145
Kidney ..... 146
Stomach ..... 146
Sebaceous ..... 147
Mammary ..... 147
Thyroid Bodies ..... 149
Spleen ..... 151
Seudoriferous ..... 152
Racemose ..... 162
Cowper's ..... 268

Heart ..... 24
Movements ..... 24
Aurucular Systole ..... 24
Ventricular Systole ..... 24
Apex Beat ..... 24
Sounds of ..... 24, 25
Inervation of ..... 25
Depressor Nerve ..... 26
Action of Sympathetic Nerve ..... 27
Hunger, Sensation ..... 100
Heat, Animal ..... 163
Heat, Lost and Gained ..... 164
Hearing ..... 243
Hearing, Mechanism of ..... 243, 248

Insalivation ..... 104
Intestine, Small ..... 119
Intestine, Large ..... 124
Inspiration ..... 65
Iris ..... 233

Katabolism ..... 137
Kidneys ..... 146, 155, 161
Kidneys, Blood Pressure ..... 161

Lymph ..... 127
Vessels ..... 128
Vessels, Inervation ..... 129
Movement ..... 130
Pressure ..... 131
Light and Color ..... 236
Locomotion ..... 254, 258
Locomotion Levers ..... 256
Lungs ..... 22, 61
Larynx ..... 61
Liver ..... 146
Muscular Tissue ..... 41
Irritability ..... 42

Sympathetic System....223
Special Senses....224
Sense of Taste....225
Sense of Smell....226
Sense of Vision....227
Sense of Vision Defects....229
Sense of Touch....240
Sense of Hearing....243
Sense, Muscular....250
Semi-circular Canals....248
Skin....23, 151
Spleen....23, 151
Sweat....153
Sebaceous Glands....154
Sensory Area....191
Salivary Glands....145
Secretion of Various Organs..143 to 151
Spinal Cord....194 to 198
Tissue Corpuscles....19, 20, 23, 38, 40
Tissue, Adipose.... 98
Trachea.... 62
Urine, Substance and Mechanism 156, 159
Vasso-constrictors.... 33
Vasso-dilators.... 35
Ventricles (see Heart).
Vomiting....111
Vision Defects....229
Voice....251
Voice Mechanism....252
Vocal Cords.... 62
Wind Pipe.... 62

# Explanation.

At the commencement of publication of the following lectures, which was a month after the beginning of the course, the first 47 pages of the book were left until copy was prepared on first lectures, index, and introductory; thus it will be understood why the numbering of pages begins with 19,—on account of an over estimated number of pages required.

Page 51 was repeated, and pages 167, 168, 169 and 170 were omitted in numbering.

The book, as it is, contains the full course of lectures as delivered to the class.

# Physiology

The vast field of nature is divided into inorganic beings possessing common properties of matter, and of organic or living beings obeying particular laws.

The inorganic being is found first in simple elementary substances not capable of analysis, and complex substances admitting of analysis and decomposition.

Organized beings exist under the forms of vegetable and animal life. In this division, while we differentiate nature, we must remember the mutual dependance which demands simultaneous existance. For example, vegetable life derives nourishment from inorganic bodies which are unfit for animal use until vegetablized; preparing it for animal food.

Discussions have led up to the difference between organized and unorganized bodies. The latter have been found very different from those endowed with life. In the homogeneous nature of their substance is the complete independence of their molecules, each of which has within itself causes to account for its peculiar mode of existence, in the power of resisting decomposition and in the absence of those powers which free organic bodies from the absolute dominion of physical laws. We cannot get an adequate conception without comparing those beings which have life with those bodies which have no life.

1. Difference between organic and inorganic is to be found in the homogeneousness of the lattter and the compound nature of the former.

2. Organized beings cannot live or exist in their natural condition unless solids and liquids enter into their combination. In the mineral substance the water or fluid which enters into it does not form a part of it. That is its existence is solid, not solid as found in the vegetable and animal kingdom.

Human physiology is the study of the different processes observed in the living body in a state of health. It considers the work or function of the various tissues and organs of the body. Some of the processes observed in the body are physical others are chemical, while those which cannot be explained by known chemical or physical laws are termed vital and are regarded as the result of vital force or life. Vital activities are manifested by living corpuscles only. These are always composed of a material spoken of generally as protoplasm which when subjeted to chemical analysis is found to consist of albuminous substance with which are associated probably always carbohydrates and fats in small proportions. The special properties of living corpuscles are:

1. Power of nutrition or assimilation.
2. The power of reproduction.
3. The possession of irritability.

Nutrition includes those processes by which the new matter necessary for growth are introduced and made part of the system. It also considers the means by which the waste material resulting from the activity of the corpuscles is got rid of. Reproduction is the power which a corpuscle has of separating some portion of its own substance to form a new corpuscle. Irritability is the property by means of which the living corpuscle exhibits active changes under the influence of external and other circumstances; in other words the power of responding to a stimulus.

The human body is made up of an immense number of living corpuscles which are arranged in different groups or tissues, each tissue conferring some special benefit of the organism as a whole. The corpuscles of the different tissues differ from one another in shape and also to some extent in chemical composition. One tissue differs from another in the nature and amount of the material lying between the corpuscles and binding them together, intercorpuscular substance. Each corpuscle if it is to live and to work must receive a constant supply of O and a constant supply of nutriment. As the activity of the corpuscle involves the destruction or rather chemical changes resulting in the formation of waste products there is a constant necessity for the removal of these products from the corpuscles. New materials and O are brought to the corpuscles by the circulation of the blood and the same way, at least in part, waste matters are removed from the neighborhood of the corpuscles. Thus each corpuscle is an organism in itself taking up nutriment and O and sending its waste products into the blood. If the blood is to fulfill this function new nutriment and O must be regularly supplied to it and the waste matters be eliminated. For the performance of these functions there are different systems or groups of organs. Thus nutriment matter is taken into the alimentary system and there prepared for its passage into the blood. The absorbent system is engaged in transferring the matter so prepared from the alimentary system into the blood. By means of the circulatory system the blood is sent to all parts of the body so that every corpuscle receives the necessary nutriment and O, the latter having passed into the blood as it circulates through the lungs and the respiratory system. On the other hand the excretory system is engaged in freeing the blood from waste products which it has brought away from the various tissues of the body. By means of the muscular and osseous systems various advantages and necessary movements are rendered possible and to the special organs of the reproductive system are devoted the propagation of the species. Presiding over the whole of this is the nervous system bringing different parts of the body functionally together, securing them properly, co-ordinating their action and bringing them into special relation with the external world, while through certain parts of the system (the cerebral hemispheres) the mind acts on the matter of the body which is influenced by physical forces.

CHEMICAL COMPOSITION OF THE BODY:—The different processes that are active

in the body are either physical, chemical or vital. To understand the working of these it is necessary to be acquainted with the structure of the body, its anatomy and physiology, and also its relative chemical composition. The changes of the body are so largely chemical that to understand these we must have a knowledge of body chemistry.

Like other living organisms the human body yields many substances of a highly complex chemical character. The chemical composition of the tissues cannot be determined accurately during life as chemical analysis destroys their vitality For these reasons the vital chemistry of the body is only imperfectly understood. The living corpuscles of the tissues are mainly composed of proteids or albuminoids, varying somewhat in composition in the different corpuscles. Thus while blood corpuscles may be said to consist of undefferentiated protoplasm, while the protoplasm of the muscle corpuscle has undergone some chemical changes in its composition in connection with the specialization of its function it receives the name myosin. Besides proteid matter there are present in the body a certain proportion of carbohydrates, fats, saline matters, gases and water as well as the various substances found between the corpuscles in the tissues and which may be regarded as built up by the activity of the corpuscles. There are also waste matters, the products of vital activity. Of these several classes many examples occur, all of which may be reduced to six groups of what are called the proximate principles.

The proximate principle is a chemical composition in which compound bodies combined in living matter can be separated as such by purely chemical processes. Thus sodium chloride is a proximate principle of the body because it is found in the body as such. Sodium on the other hand is not a proximate principle because, though it exists in the body, it is never free as sodium but always a chemical combination with some other element or elements. For the same reason phosphate of lime is a proximate constituent of bone, but phosphoric acid and cloride of calcium are not proximate constituents for they do not exist individually in bone but united they form the salt.

PROXIMATE PRINCIPLES OF THE BODY :—

1. Water. This is present in all the tissues forming about two-thirds of the weight of the body.

2. Salts, for example the chlorides and phosphates of sodium and calcium. Sodium chloride is found in all the fluids and tissues. It may be remembered that the sodium salts are found most abundantly in the fluids and potassium salts chiefly in the solids of the body.

3. Gases. $Co^2$, O and N found in the blood and other fluids.

4. Carbohydrates. Found chiefly in vegetables tissues. Some are found or formed by animal organisms; a. grape sugar or dextrine found to a limited extent in the various fluids of the body, sometimes abnormally large in diabetes. b. Glocogen or animal starch in the liver, muscles and etc. c. Inosit or muscle sugar found in small quantities in the muscles of the heart and elsewhere. d. Lactose or milk sugar found in milk. Lactic acid is said to be formed from the carbohydrates as it is found in the muscles and other parts.

5. Fats. The principle fats of the body are formed by the union of a fatty

acid with a compound base known as glycerol, a triatomic alcohol consisting of of three atoms of hydroxyl united to a radical glyceryl. These are, a. olein or oleate of glyceryl with oleic acid. b. Palmitin or palmitate of glyeryl with plametic acid. c. Stearine or sterate of glycerol with stearic acid. The fat of the body exists during life in the fluid condition and consists principally of olein and stearin. Glycerol is the base present in glycerine which is the hydrate of glycerol.

6. Nitrogenous substances. These in addition to C, H, and O contain N. They are a very important sort of bodies and may be divided into two kinds, a. proteids or albuminoid substances, b. substances allied to proteids. a. Proteids. These most important substances occur in animal organism. They are complex substances all containing C, H, O and N with a small quantity of sulphur. Among them we find myosin obtained from muscles: globulin in the red corpuscles of the blood; fibrin formed when the blood coagulates; casein found in milk; and the peptones formed in the stomach during digestion. b. Substances allied to proteids. These are mucin found in mucus; elastin the basis of elastic tissue; kreatin found chiefly in hair, nais and epidermis scales; neoro-keratin found in nervous tissues, chiefly in the brain; gelatin obtained from white fibrous tissues and from bones by prolonged boiling; chordrin obtained from the intercellular substances of hyaline cartilage by boiling. Both gelatin and chrondrin are soluble in boiling water and the solution of each forms a jelly on cooling. Solution of gelatin gives an insoluble precipitate only tannic acid and mercuric chloride, but chrondrin is also precipitate by acetic acid, mineral acids, alum, lead nitrates and acetates. Creatin, xanthin, urea and uric acid along with numerous compounds are products of the breaking down of the nitrogenous substances of the food tissues.

7. Besides the above groups there are sometimes classes with the proximate principles pigments of the body, for example, haemoglobin, the coloring matter of the red corpuscles.

# Blood and Circulation.

It is evident that new materials from a variety of sources are continually passing into the blood. Arrangements exist by which waste matter received into the blood from the tissues is drained off from the blood and ejected from the body.

The blood is kept of a uniform character. and is maintained in a condition of efficiency for the discharge of its duty in the various tissues of the body. New material reaches the blood vessels through different channels. These channels are five in number:

1. Alimentary canal. Some blood passes directly from the canal into the blood vessels, but in general the blood has to pass through the liver before reaching the general circulation. Fatty substances are also absorbed by lacteals by which they are conveyed to the lymph glands.

2. The lungs. Oxygen passes in this way to the blood.

3. The tissues generally Through the lymphatics, e. g.. water with salts and nitrogenous matter.

4. The skin. Oxygen is absorbed in this way to a slight extent.

5. The spleen. the lymphatics and bone marrow and to a slight extent the tissues which supply white corpuscles.

The coloring matter of the blood is contained in the red corpuscles of which it forms as much as 90 p. c. The coloring matter consists of a compound of hæmatin associated with globulin. This may be obtained in the form of crystals, (which in the human body are four-sided prisms) by various processes; example. by alternate freezing and thawing which causes the disintegration of the corpuscles.

Though a crystaline body it has a very low diffussive power. Hæmatin itself is an amorphus powder containing carbon, hydrogen and oxygen. Hæmogloblin is loosely associated with a quantity of oxygen, hence is sometimes called oxy-hæmoglobin, and it is to this compound that the color of the arterial blood is primarily due. This combination is not a very stable one, the liberation of oxygen taking place quite freely.

The reduced hæmoglobin proper is of a purplish hue and it is the color of this substance that venous blood depends upon mainly for its color. There are various chemical tests to ascertain the character of the blood.

Gases of the Blood:—By means of a sprengel pump there may be extracted from blood gas at the ratio of 60 volumes of gas in every 100 of blood. The composition of this gas differs in arterial and venous blood, as follows: In arterial blood there are 20 vol. of O, from 1 to 2 of N, 40 vol. of C. In venous blood there are 8 to 12 vol. of O, 1 to 2 of N, 46 of C. Only a very minute quantity of O exists in the blood, dissolved or absorbed by the law of partial pressure, the main volume of O is associated with H. It is certain, however, that this gas is not merely dissolved in the blood. Under the law of partial pressure when the blood is placed in a partial vacuum the greater part of $CO^2$ escapes, but a small quantity may after be obtained by an acid. The main volume would therefore seem to be loosely associated with some substance or substances in the blood while a small porportion is in complete chemical combination. The N in the arterial and venous blood is present in a state of simple solution.

Circulation of the Blood:—The vascular system is a system of closed tubes which contain a fluid—blood.

In the circuit of the fluid there is a pump—the heart—which drives the fluid through the vessels, the flow being maintained always in the right direction by means of valves. The heart itself is a hollow muscle divided into a right and left lateral side, each half having two cavities, the auricle and ventricle, communicating with one another through the auriculo-ventricular opening, guarded by a valve which hinders regurgitation. The flow of blood is as follows: The blood returning from the tissues is poured into the heart by the superior and inferior venæ cavæ; from the right auricle to the right ventricle whence it is driven into the pulmonary artery and through the lungs. After the circuit through the lungs it is returned through the pulmonary veins to the left auricle thence to the left ventricle and into the

aorta, from whence it passes to the other arteries, then into the smaller arteries and into the capillaries, and from the capillaries to the venous circulation, coming back to the right auricle by the venæ cavæ. The blood is prevented from being forced back into the auricles by the closure of the tricuspid valve on the right side and the mitral valve on the left, while regurgitation into the ventricles after being driven into the aorta and pulmonary artery is prevented by the closure of the semi-lunar valves.

The heart is constantly going through a series of movements constituting a cycle or period of revolution, corresponding parts of the heart acting at one and the same time. This action of the heart has three elements:

1. Auricular systole is the contraction of the auricles; contraction occupying one-fifth of the period of the cycle of revolution.

2. The ventricular systole, contraction of the ventricles, occupies two-fifths of the period.

3. The period of rest. The whole heart during the period of rest is relaxed in diastole, and occupies two-fifths of the period.

The points of difference between the auricular systole and the ventricular systole may be noted.

AURICULAR SYSTOLE.

1. Precedes the ventricular systole.

2. Occupies one-fifth of the cycle of the heart's action.

3. The contraction is gradual and does not persist.

4. Relaxation is slow.

5. Precedes the apex beat.

VENTRICULAR SYSTOLE.

1. Follows the auricular systole.

2. Occupies two-fifths of the cycle of the heart's action.

3. The contraction is sudden and persists sometimes.

4. Relaxation is rather slow.

5. Corresponds with the apex beat.

APEX BEAT:—The apex beat is seen and felt in the fifth intercostal space, a little within the vertical line of the nipple, and is due to sudden contraction of this portion of the ventricle as brought into contact with the chest wall during ventricular systole, by the stimulation of its right and left diameter. The apex beat corresponds with the commencement of the ventricular systole which consists of three stages. These beats are from 65 to 75 or 80 beats per minute, the frequency of the beat being influenced by age, health, food, exercise and mental state.

SOUNDS OF THE HEART:—The sounds of the heart are two in number for each cycle of the heart's action: the first, the long or systolic sound which is heard best over the apex; the second, or short sound, sometimes called the diastolic sound, heard best over the base of the heart. After the 2nd sound there is a period of silence or pause before the 1st sound occurs again. Hence the rhythm of the cardiac sound is, 1st sound, 2nd sound, pause; 1st sound, 2nd sound, pause, etc. The first sound is longer and more dull than the second and somewhat booming in character (bow-bow sound). The exact cause of the sound is not known, but it has been variously regarded as being caused by the vibrations of the auriculo-ventricular valves, by some as the rush of blood through the orifices of the aorta and pulmonary artery, by others as the muscle sound produced by the contraction of

the fibers of the ventricles, by others as a combination of all these causes.

The diastolic sound is short and sharp. It is undoubtedly due to the sudden tension of the aortic and pulmonary semi-lunar valves, as when one of the flaps of the aortic valve is hooked up by a needle the second sound disappears to a murmur.

The sounds of the heart indicate what is going on in the heart at any particular moment.

During the first sound the following phenomena occur:

1. Contraction of the ventricles.
2. Rush of blood through the orifices of the aorta and pulmonary artery.
3. Closure of the auriculo-ventricular valves.
4. Apex beat.
5. Auricles in diastole, the blood passing into them.

During the second sound these phenomena occur:

1. Closure of the semi-lunar valves.
2. Ventricles relaxing.
3. Opening of the auriculo-ventricular valves.
4. Auricles in diastole, still filling with blood.

During the pause or period of silence we find:

1. Blood is passing into the auricles and from the auricles into the ventricles, the whole heart being in a state of diastole.
2. Just before the first sound is heard again the auricular systole occurs. N. B. Auricular systole immediately precedes the first sound and apex beat. It does not produce any sound.

Innervation of the Heart:—The heart of a warm blooded animal ceases beating almost immediately upon the removal of the heart from the body. In the case of cold blooded animals like the frog, it remains beating often after death for some hours or days. If a portion of the heart is cut off from the apex of a palpitating frog's heart, the separated portion ceases to beat by the division of the heart. It still possesses power of irritability from the fact that it will still respond to stimulation, e. g., electric currents. The contraction of cardiac fibres of the heart must arise from nervous stimulation, and this stimulation originates from ganglia within the heart itself.

In addition to this the movements of the heart go on just as well when the cavities of the heart are empty as when the blood is circulating through them. It is evident that the centers in these ganglia are acting automatically and not as was once supposed under the influence of the blood entering the cavities of the heart.

The nerves of the heart are derived from three sources.

1. From the intrinsic cardiac ganglia which are lodged in its own substance and especially collected about the auriculo-ventricular sulcus. These probably give rise to its rhythmical movements. The nervous cords passing to the heart from the central nervous system are two in number:

1. Cardiac branches from the vagus.
2. Fibres from the lower cervical and the upper thoracic ganglia of the sympathetic, these give us the stimulus by which the heart is excited to increased action by joy or other emotions. It receives branches from the pneumogastric or 10th pair of cranial nerves which come directly from the brain; these exert an

inhibitory influence on it, in some cases stopping the action of the heart, as in the case of death by fright. If the pneumogastric be cut in two, the heart beats more quickly, while if the cut portion of the peripheral part be stimulated the heart's action will be slowed and in some cases completely suspended. The influence of the pneumogastric therefore upon the heart is inhibitory. It would appear that this nerve acts not directly upon the muscular fibres of the heart but on the intrinsic ganglia. The stoppage of the heart produced by the strong stimulation of this nerve is not due to tetanus. This is clear from the fact that the heart stopped under these circumstances is not in a condition of contraction but of relaxation, that is the heart is in a diastolic condition.

The action of the sympathetic differs from that of the vagus in four particulars:

1. Its action is that of acceleration.

2. A more powerful stimulus is required than in the case of the vagus.

3 It takes a longer time to produce the result.

4. The acceleration is followed by exhaustion, the beats after a time becoming feeble and less frequent.

Depressor Nerve:—The fibres of this nerve are blended with the pneumogastric. If the small arteries of the body are in a state of extreme contraction there will be a great resistance to the action of the heart. Under these circumstances a strong impression is sent from the heart along the depressor nerve to the center in the medulla called the vaso-motor center. This center is engaged in originating impressions transmitted outwards which keep the muscles of the small arteries in a state of contraction.

This center would appear to be constantly engaged in origination of impressions which are transmitted outwards and which keep these muscular fibres of t he small arteries in a constant state of contraction. The impression which under the circumstances we have mentioned is sent along the depressor nerve from the heart to the vaso-motor center, inhibits this center and its activity being thus restrained, the small arteries dilate. Thus the extreme resistance to the cardiac contraction is removed. The presence of the depressor fibres explains the fact that the stimulation of the cut end of the central portion of the 10th nerve causes dilatation of the small arteries and a consequent fall of blood pressure. As the depressor is blended with the sympathetic the stimulus reaches the vaso-motor centers through the depressor fibres and the vaso-motor fibres being inhibited the blood vessels dilate. The vagus arises from the gray matter on the floor of the fourth ventricle. It passes from the bulb by 12 or 15 bundles behind the 9th nerve and passes from the skull by the jugular foramen, giving off certain branches and receiving certain branches from the glosso-pharyngeal and spinal accessory nerves. This junction of the vagus and spinal accessory gives to it its cardiac inhibitory functions. The spinal accessory being the cardiac inhibitory center. The depressor is one branch of the vagus differing from the inhibitory branches, it is afferent not efferent and bears the impulses to the vaso-motor center from the heart. In most animals the depressor nerve is bound up in the trunk of the vagus. The normal function of this nerve (the depressor) is to adapt the heart's action to peripheral resistance,

impulses being borne by this nerve to vaso-motor center in order to lessen the resistance. The depressor is different from inhibit ry action. Stimulation of the peripheral end of the vagus produces a fall of blood pressure due to inhibition of the heart. Stimulation of the central end of the depressor nerve lowers the blood pressure, due to reflex relaxation. That is the difference between the depressor and the vagus in general. Hence the influence and function of the depressor nerve is that of lessening the peripheral resistance.

Action of the Sympathetic Nerve upon the Heart:—The fibers from the sympathetic ganglion act as an accelerator of the heart's action; hence the action of the sympathetic is the reverse of that of the vagus, and if they are cut or injured in some way the heart is slowed being handed over to the influence of the pneumogastrics. If the sympathetic is cut and the cut end of the peripheral portion is stimulated, the heart will beat more quickly due to restored stimulation in the sympathetic. If stimulation be severe and long continued the heart will not pass into a state of tetanus, but after quickening speed for a short time will return to its original rate. The sympathetic nerve fibers, therefore, do not act directly on the heart muscle, but upon the intrinsic cardiac ganglia causing these to give out their reserved stock of energy. When this reserve stock is exhausted the stimulation of the sympathetic will cease to accelerate the action of the heart.

Reflex Fibres in the Sympathetic:—When the cut end of the central or cephalic portion of the sympathetic is stimulated the heart's action is slowed. This is explained by the fact that certain fibres in the sympathetic communicate through a center or through centers with the pneumogastric. Hence stimulation of these fibres arouses the activity of these centers and this stimulation is actively communicated to the pneumogastric. The result is the cardiac ganglia are inhibited and the action of the heart is slowed. This center with which the inhibitory fibres of the pneumogastric are connected is in the medulla. The cardiac fibres of the sympathetic take origin in the upper part of the spinal cord. They pass to the heart from the anulus of Vieussens and cervical sympathetic in the superior, middle and lower bundles of fibres. The vagi nerves simply convey an inhibitory or restraining influence over the heart's action, which is carried through them from the center in the medulla. This restraining influence may be reflexly increased by the stimulation of the afferent nerves, especially the abdominal sympathetic producing slowing and even stoppage of the heart's action. Hence a violent blow upon the epigastrium may stop the heart's action.

This is due to the conveying of the stimulus by afferent fibres (sympathetic) to the medulla and its subsequent reflexion through the efferent. the vagi, upon the muscular substance of the heart.

Circulation in the Blood Vessels:—Circulation through the vessels is accomplished by the heart, which is the initial propelling force. The pressure in the heart is greater than in the arteries. Arterial pressure is greater than that in the capillaries and is lowest in the veins lower than in the capillaries. The fluid is always flowing in the direction of the lowest pressure. From the heart the

blood is driven into the highly elastic arteries, which dividing again and again lead into the capillaries through which the blood passes into the feeble elastic veins which return it to the heart. As the arteries divide the sectional area of the arterial system increases so that the united sectional area of the capillaries is much greater than that of the aorta at its commencement, some say 800 times greater, The sectional area of the venous system on the other hand decreases from the capillaries to the heart, but the united sectional area of the two venæ cavæ at the right auricle is nearly twice that of the aorta at its origin. The blood therefore in travelling from the heart to the capillaries is passing into a wider and wider area while reverse is the case in its course from the capillaries to the heart through the veins.

The blood current velocity at any one point in the circulation is in inverse proportion to the sectional area at that point. Hence the rapidity of the circulation diminishes from the heart to the capillaries but increases again from the capillaries to the heart. It is more rapid in the larger than in the smaller veins. The blood when driven by the force of the ventricle into the vessels exerts pressure called blood pressure This pressure will be greatest in those parts nearest the force (the arteries ) This pressure is sufficient to keep the elastic arteries in a state of distention by stretching the elastic elements in their walls, and this state of distention will be increased at each contraction of the ventricle. This tension—arterial tension—reacts on the blood, not only opposing peripheral resistance to the action of the blood, but also changing the intermittent current produced by the alternate systole and diastole of the ventricles into a continuous flow. Hence the blood runs in an even current through the capillaries and veins. The blood pressure in the veins is slight because the veins are far removed from the force of the ventricular systole. The blood pressure in the veins is so low that those vessels are far from being fully distended. If the veins are fully distended they alone are capable of easily accommodating the whole volume of blood circulating through the body. In the arteries there is a quantity of muscular tissue under the control of the nervous system. By the contraction and relaxation of these muscular elements the calibre of the vessels, and therefore the peripheral resistance can be increased or diminished. If the relaxation or contraction is local the amount of blood in any part of the body may be reduced or increased as occasion requires.

Circulation in the Arteries:—The contraction of the left ventricle forces a certain amount of blood into the aorta. At each beat the left ventricle forces about four ounces of blood into the arterial system. The aorta being elastic distends as soon as the ventricle relaxes. The force which causes the distension of the aorta being removed the vessel recoils and springs back. As the blood can not regurgitate into the ventricle in consequence of the closure of the semi-lunar valves it is forced outwards producing distension of the succeeding part of the aorta, which distends and recoils in the same manner. Hence an alternate distension and recoil travels along the arterial system constituting the pulse wave. The pulse wave gradually diminishing in amplitude travels along the arteries at

the rate of nine meters per second. It is quite distinct from the rapidity of the circulation, that is the current of the blood which is not more than one-half meter per second even in the larger arteries and diminishing gradually in the smaller arteries. The rapidity of the flow of blood is about 30 times slower than the pulse wave. The pulse wave reaches the radial artery about .15 seconds after the systole of the ventricle as felt at any one point. The pulse is due primarily to the contraction of the left ventricle and directly to the recoil of that part of the artery immediately behind the point where the pulse is felt. The pulse is not caused by the fluid or circulation of the fluid, but is the transmission of a wave like movement along the walls of the vessels. The pulse has nothing to do with the current of the blood, but is due to undulatory movements along the walls of the arteries and consists of distention and elastic recoil. The more distant from the heart the artery is, the longer is the interval between the ventricular beat and the arrival of the pulse. Thus, the pulse is felt in the carotid artery earlier than in the radial artery and is still later in the dorsal artery of the foot. Physicians usually feel the pulse in the radial artery because it is close to the surface and supported by bone. In noting the pulse it is necessary to know first, the number of beats per minute which gives us the rate of the heart beat; second, the length of time each beat occupies; third, the character of the beat, wheather strong, weak or bounding; fourth, whether regular or irregular; fifth, the force necessary to destroy or compress it. This gives us the peripheral resistance and also the conditions of the arterial walls. The actual changes which occur at any one point where the pulse is felt are as follows: First, temporary extra extension of the artery and to a slight extent also a lengthening, this expansion being due, second, to the temporary local increase of blood pressure, and third, to the recoil or springing back of the arterial walls from the resilieney of the elastic elements which it contains. The movement of the pulse is studied by means of the sphymograph, having a series of levers, on one end of which is a button placed over the artery, the other end being provided with a writing point to inscribe a magnified record of arterial movement on the travelling surface of of smoked paper. The sphygmoscope is used for the purpose of seeing the pulse movements by a gas flame. In a pulse tracing the upstroke, which is nearly vertical, corresponds to the sudden expansion of the vessel and the downstroke, which is more oblique, corresponds to the more prolonged elastic recoil. On the downstroke there are two or more marked waves, the first called the tidal wave, the second the dicrotic wave or notch. The wave above is called the predicrotic, the wave below postdicrotic, and the medial wave the dicrotic proper. In some cases there is a secondary wave on the upstroke called the anacrotic. The dicrotic wave is caused by the closure of the semi-lunar valves, these closing with a sudden jerk and the shock is felt on both sides. A short upstroke and a regular downstroke constitute a pulse of high tension, that is the walls of the blood vessels are as it were extra tense yielding but slightly to the wave of the pulse and springing back after expansion with but little oscillation. An

exaggerated upstroke and the waves, especially the dicrotic wave, on the down stroke, will constitute a pulse of long tension or a dicrotic pulse (peripheral resistance.) The arterial wall in this case is comparatively lax and easily yields to the force of the pulse wave, springing back not in a firm and decided manner, but oscillating to an extreme degree. The nature of the pulse at any time and in any portion of the arterial system depends upon the following:

1. The contraction of the left ventricle.
2. The pressure of the blood.
3. The tension of the arterial wall.

This pulse wave motion indicates the health condition. In the cold water bath we have what is called the hard, incompressible pulse due to the contraction of the small arteries. In the hot water bath we have what is called the soft compressible, bounding pulse due to the dilation of the small vessels. There is less blood in the deep vessels, and hence the readiness to extend owing to the great elasticity and the pressure of less blood. The normal pulse rate in the male is about 72 and in the female from 5 to 8 more. At birth it is above 140 gradually decreasing till about the 15th year when it is found to be about its normal—75.

Capillary Circulation:—The current of blood in the capillaries is continuous, that is, there is no pulse a result of the elasticity of the arteries. The smallest capillaries admit only of a single corpuscle, and the corpuscles can be seen accommodating themselves to the calibre of the vessels. In vessels a little larger than these ultimate capillaries, the red corpuscles pass quickly along the middle of the vessel while the white corpuscles glide more slowly along the capillary wall, through which some of them escape. This is called diapedesis. The chief cause of this is the vital power of mobility and contraction possessed by the corpuscles, not the capillary walls. It takes place normally to a slight extent in a condition of health; in this condition both red and white pass through the walls, but it is largely increased during inflamation, and may go so far as to form an abscess consisting of a collection of dead leucocytes outside of the vessel. These are called in this condition pus corpuscles. An individual capillary, if closely watched, may be seen to vary but slightly in its calibre at different times, showing that the capillary walls possess a definite degree of contractility. The abundance of the capillaries in any tissue or tissues is always in proportion to the activity of the tissues and in certain tissues they have a characteristic appearance. For example, in striped muscle they are between the fibers; in the intestinal villi in loops; in the mucous membrane of the stomach they form an irregular net work; in the mucous membrane of the colon they have a honey-comb arrangement around the orifices of the tubular glands.

The forces which act in capillary circulation are as follows:

1. The contraction of the left ventricle, the flow being modified by the elasticity of the arteries.

2. Contraction of the muscle, the proper direction of the flow being secured by means of the valves in the veins, and the flow being made continuous by the elasticity of the arteries, vis a tergo.

3. The tissues themselves have been

regarded as exerting an attractive force on the blood, as it were, drawing the blood to them, vis a fronte.

Venous Circulation:—The blood current in the veins is a coutinuous one, (that is, there is no pulse.) The flow, as we have already seen, becomes gradually more rapid from the capillaries to the heart. This is due to the fact that the bed of the current is becoming gradually diminished. The circulation in the veins is due to:

1. The contraction of the left ventricle, the flow being modified by the elasticity of the arteries.

2. The contraction of the muscles (external voluntary movements); the proper direction of the flow being secured by the valves in the veins.

3. The suction action of the auricle or of the veins opening into it.

4. The suction action of inspiration on the great veins passing through the thoracic cavity to the heart.

Muscular paessure on the veins assists in pushing the blood onward in the course of circulation and also in pressing backward to close the valves behind the circulation. By the close communication of the veins one with another, this backward pressure does not retard the circulation of the blood, for the blood that is stopped by this backward pressure can find other venous channels through which to escape, on account of the free venous anastomosis.

Blood Pressure:—By this is meant the pressure that is exerted on the walls of the blood vessels. If a large artery be connected with a mercury manometer or pressure measurer in such a way that while the blood is able to flow on uninterruptedly through the vessels there is free communication between the interior of the artery and the descending limb of the manometer, the mercury in the ascending limb of the instrument at once rushes up to a certain height showing that pressure is exerted outward by the blood on the walls of the artery. The height of the mercury, that is, the force of the blood pressure, is distinctly increased at each ventricular systole and falls again with each ventricular diastole. There is further a more marked elevation of the murcury during inspiration and a corresponding fall during expiration. By causing the oscillations of the mercury to be recorded on a traveling surface, the tracing may be obtained which corresponds with the blood pressure (kymographic tracings). The blood then exerts on the walls of the artery at each point a certain mean pressure, this pressure varying with the force of the ventricular systole, with the distance of the point from the left ventricle and the state of the contraction of the arteries. The pressure diminishes as it passes from the heart to the periphery and attains its maximum at the moment of the systole of the ventricle. The causes of the blood pressure are:

1. The contraction of the heart.

2. The condition of the peripheral resistance.

Blood pressure increases after eating a meal or from any other cause which makes the heart beat faster without dilatation of the vessel. The pressure at any one point is increased during the ventricular systole and diminished during the ventricular diastole, and is also modified by the inspiratory movements, diminished during expiration and increased during inspiration.

1. The mean blood pressure is high in all the arteries. It is greater in the larger arteries nearer the heart than in the smaller arteries farther from the heart. This mean pressure on the arterial wall diminishes along the arterial system toward the capillaries, being less the farther the vessel is removed from the force of the contraction of the left ventricle. The oscillations of pressure due to the alternate ventricular systole and diastole are more marked in larger than in smaller arteries, the currents in the latter, on account of the high degree of elasticity of the larger arterial trunks, the more nearly approach the continuous flow.

2. In the veins the blood pressure is very slight compared with the blood pressure in the arteries and it is less in the larger than in the smaller veins, the former being farther removed from the force of the ventricular systole. In the large veins close to the heart, the pressure is at times negative on account of the suction action of inspiration and the suction action of the auricles. The pressure in the veins nearer the heart is about 1-10 of that of the arteries nearer the heart. The pressure is higher in small veins, the great veins may even have negative pressure. The positive pressure is the atmospheric pressure plus the extra pressure in the system. The negative pressure is the atmospheric pressure minus the same pressure by suction. The negative pressure may be from .1 to .5 in the opposite direction. In this way there is produced in the larger veins alterations of blood pressure and a kind of venous pulse. With this exception the flow of blood, under ordinary circumstances, in the veins is even and constant and there is not at any one point any alternate rise and fall of blood pressure as in the case of the arteries. Increase of arterial blood pressure is produced by the increase in the rate of the heart, increase in the quantity of the blood and the contraction of the arterioles. Decrease of arterial blood pressure is produced by decrease in the rate of the heart, decrease in the quantity of the blood and decrease in the contraction of the arterioles. Venous blood pressure is increased by a decrease in the rate of the heart, increase in quantity of blood and decrease in contraction of the arterioles. Venous pressure is decreased by increase in the heart's rate, decrease in the quantity, and increase in the contraction of the arterioles.

3. When the skin is pressed upon it becomes pale and bloodless due to the pressure driving the blood out of the capillaries and blood vessels and preventing fresh blood from entering. By investigating the amount of pressure necessary to accomplish this we may approximate the internal pressure which the blood exerts on the walls of the capillaries and minute vessels. In the frog it is estimated at about 7 to 10 m. m of mercury, and in the mammals at about 25 to 30 m. m.

4. There is a continuous decline of blood pressure from the aorta through the arteries and veins to the right auricle, the most marked fall of pressure being between the small arteries on one side of the capillaries and the small veins on the other side.

5. In the arteries this mean pressure is marked by oscillations corresponding to the heart beats, each oscillation consisting of a rise corresponding to the

systole and a fall corresponding to the diastole of the ventricle. These oscillations are greatest in the larger arteries nearer the heart, diminishing from the heart to the capillaries and are normally absent from the capillaries to the heart.

VELOCITY OF CIRCULATION:—Various instruments have been invented for measuring the rapidity of the blood current but no results have been attained which can be received as accurate. The rapidity of the blood as seen already gradually diminishes from the heart to the capillaries along the arterial system and increases in the veins from the capillaries to the heart.

INNERVATION OF THE BLOOD VESSELS:—The arteries throughout the body are connected with nerve fibres which though running in the main sympathetic tracts can be traced into connection with the cerebro-spinal system. Each nerve has its own vascular area and on cutting any one of these the arteries in the vascular areas over which the nerve presides dilates as is shown by the redness and increased temperature of the part. Stimulation of the cut end of the peripheral portion of the divided nerve causes the arteries to contract again. How these nerves terminate in the arteries is uncertain, but it is evident that in some way or other they keep the muscular fibres of the walls of the vessels in a certain state of tonic contraction. And so by their influence they lessen the calibre of the vessel. Hence they are called vaso-constrictor fibres. The vaso-constrictor fibres are governed by a center in the medulla, for when this is destroyed the arteries all over the body dilate, the vaso-constrictor influence being removed and consequently the blood pressure falls. Similar effects may be produced by inhibition of the this vaso-motor center. This may result either from the nervous impressions reaching it from the higher centers under the influences of emotion, joy, fear, shame etc., or as a result of stimulation of different nerve fibres, e. g., the depressor nerve of the heart. In each case the activity of the vaso-motor center is restrained, the nervous impressions therefore cease to pass from it along the vaso-constrictor fibres to the blood vessels and these vessels dilate. Besides this general vaso-motor center in the medulla there are other centres which in a similar manner preside over and regulate the state of contraction of the arteries in particular areas of the body; these are subsidiary to the general center. The nervous influences already referred to are of such a nature that when active they produce contraction of the arteries while, when they cease to act dilation of the vessels necessarily results. But there are nerve fibres the active stimulation of which produces not contraction but dilation of the vessels. These fibres are called vaso-dilators. The dilation of the arteries of the submaxillary glands on stimulation of the chorda tympani and the erection of the penis following stimulation of the nervi arigentes are examples of the action of nerve fibres. It is generally believed that the vaso-dilator nerves act by inhibiting nervous ganglia which are in connection with the walls of the vessels. From these ganglia nervous impressions pass to the muscular fibres of the vessel walls, keeping them in a state of tonic contraction. When these ganglia are inhibited by stimuli reaching them along the vaso-dilators the muscular elements

of the arterial walls relax and the arteries dilate. We may summarize the vaso-motor actions, thus: Most if not all of the areries of the body are connected with the central nervous system by nerve fibres called vaso-motor fibres, running in this or that nerve, the action of which varies the amount of the contraction of the muscular coats of the arteries and so leads to changes of calibre. The action of these vaso-motor fibres is more manifest and more important in the case of the small and minute arteries than in case of the larger ones. Some nerves contain only one kind of fibers, others both kinds in different proportions. Almost every nerve of the body may be regarded as influencing a certain set of blood vessels, governing a vascular area either by constriction or dilation or both. Both the vaso-constrictor and vaso-dilator fibers have their origin in the central nervous system the spinal cord or the brain but the course of the two sets of fibers is very different. These vaso-motor fibers are of two kinds, vaso-constrictor which have such connections at their central origin or preipheral ending that stimulation of these produce narrowing or constriction f the arteries. During life these arteries seem to be the medium by which the central norvous system exerts a continuous tonic influence upon the arties, maintaining an arterial tone. The vaso-dilator fibers are of such a nature or have such connections that stimulation of them produces widening of the arteries. We have no definite knowledge that these vaso-dilator fibers serve as a medium dilating influences or impulses. Vaso-constrictor fibres leave the spinal cord by the anterior roots of the nerves coming from the middle region of the spinal cord, passing into the splanchnic ganglia connected with those nerves where the fibers lose their medulla and go on as nonmedullated fibers, either as sympathetic nerves or along the recurrent branches of the splanchnic system to join the spinal nerves of the limbs and trunk. In the organism the transmision and distribution of tonic constrictor impulses along the vaso-constrictor fibers by which a general or local arterial tonè is sustained is governed by a limited part of the medulla, known as the vaso-motor center. When changed conditions, or natural changes, stimuli the activity of the vaso-constrictor fibers, either of one or more of the vascular areas or of all the areeries supplied by vaso-constrictor fibers, this vaso-motor center becomes a centerof reflex action. When nervous connection of the vaso-motor center with a vascular area is suspended by an operation or by a section of the cord, other portions of the spinal cord may act as a center for the vaso-constrictor fibers, and these secondary centers may be in active operation to a certain extent even in the solid organism. The vaso-dilator fibers seem to originate in various parts of the central nervous system and to go directly to their destination along the anterior roots and as parts of the trunk and branches of various cerebro-spinal nerves. They do not lose their medulla until they come near to their termination. They do not seem to act as media for tonic dilating influences. They are put into action generally as part of a reflex action and in this reflex action, their center seems to lie in the central nervous system not far from centers of the motor fibers which they accompany. The effects of the action

of the vaso-dilator fibers seem to be essentially local in character.

Vaso–Dilators:—When any set of them come into action the vascular area which is governed by them is dilated and this vascular area is so small that little effect is produced upon the whole vascular system. Changes in the activity of the vaso-constrictor fibres produce effects which are both local and general. By the inhibition of the tonic constrictor impulses a certain degree of dilation results. By augmenting the constrictor impulses, constriction of a marked character may result. If the vascular area affected is small the effects are local and more or less blood is distributed throughout the area. If on the other hand the vascular area is large the inhibition of constriction may lead to a decided fall and the augmentation of the constriction may lead to a decided rise in the general blood pressure. For example, blushing is an effect of vas-motor action. Emotion, joy, shame etc., by originating nervous impulses in some parts of the brain producing a very strong inhibition of that part of the medullary vaso motor center which governs the part of the vascular area of the head supplied by the cervical sympathetic affecting the vaso-motor fibres of the cervical sympathetic just in the same way as in the section of the nerves. The result is the relaxation of the muscular walls of the arteries of the head and face, arterial dilation and consequently the suffusion of the entire region. In some cases face palor occurs without any change in the heart beat, this being due to a condition the reverse of that which we find in blushing, that is, arterial constriction effected through the cerebro-spinal system and the sympathetic. In case of the skin, when the the temperature of the air around it is low the skin assumes a pale color due to the constriction of the vessels of the skin. When the temperature is high the skin is flushed, this being due to the dilatation of the vessels of the skin. In these cases augmentation of constriction and inhibition are accomplished chiefly by reflex action, although there is a direct action of the heat and cold upon the vessels. These changes in the skin are accompanied by corresponding changes in the viscera of a reverse order. For example, dilatation of the vessels of the skin accompanies constriction of those of the viscera. In this way by these corresponding changes the body preserves its normal temperature, a considerable quantity of blood ebbing and flowing from the skin to the viscera and from the viscera to the skin. The entire brain down to the upper parts of the medulla may be removed without producing any flushing or at least more than a transient flushing of any portion of the body and but a slight fall of blood pressure. This proves to us the definite existence of a nervous center in the medulla which we call the vaso-motor center from which proceeds tonic vaso-constrictor impulses and which governs the emission and distribution on these vaso-constrictor impulses over the various parts of the body. Side by side with the cervical sympathetic nerve and running along side for a considerable distance we find a very delicate nerve which can be traced down to the heart and which when traced upwards comes away high up from the vagus by two or more roots, one of which is generally a branch of the superior laryngeal nerve. This nerve (whose fibres in the dog are bound up with the vagus and do

not form an independent nerve, while in in the rabbit, cat and horse it is an independent nerve joining the vagus) seems to be an afferent nerve. After division the stimulation of the peripheral end (connected with the heart) gives no marked effects. The beginnings of this nerve in the heart, therefore, are different from the ending of the inhibitory fibres of the vagus or the augmentor fibres of the sympathetic. It has nothing to do with the nervous regulation of the heart, and stimulation of this nerve always produces a fall, never a rise, of of blood pressure, the amount of fall depending upon circumstances. This nerve is called the depressor nerve, the chief use of the nerve is to adapt the heart's action to peripheral resistance, that is, by this afferent nerve from the heart. the peripheral resistance in the living body is lowered so as to acomodate the weakened powers of a laboring heart. This gradual lowering of blood pressure by lessening peripheral resistance is in marked contrast with the sudden lowering of blood pressure due to inhibition.

THE BLOOD—The blood is equal to the amount of about 1-12 to 1-14 part of the whole weight of the body. It is an opaque fluid, scarlet in the arteries and of a purplish color in the veins, emitting a peculiar odor, having a saltish taste and giving a clammy sensation when handled. Its specific gravity is about 1050, varying from 1041 to 1075 in the health condition. In reaction it is alkaline due to the presence of the alkaline phosphates. This reaction becomes less marked as coagulation occurs. Under the microscope blood is seen to consist: first, of a pale colored fluid—blood plasma, or liquor sanguinis; second, corpuscles, red and white. Recent investigations have discovered a third and fourth kind of corpuscles, the plaques or platelets, and the granules existing in the circulating blood. These plaques are much smaller than the red corpuscles. When the blood is shed from its vessels these plaques very rapidly break up and are destroyed. The fourth kind are called the granules or granular corpuscles. Contrasting the red corpuscles and the white or colorless corpuscles, we find:

RED.

1. More numerous.
2. Circular, flat, bi-concave discs and in some cases bi-convex; about 1-3200 of an inch in diameter.
3. Non-nucleated, due to concavity.
4. Heavier than the blood plasma.
5. Consists of a stroma or net work through which the hæmaglobin is diffused. There is no definite wall, although the frame-work is more or less compact on the surface of corpuscles.
6. Origin, first, from the colorless corpuscles; second, from cells like the colorless corpuscles in the spleen and red marrow of bone.
7. Function: They carry oxygen to the tissues. In the capilaries they are seen to pass quickly along the middle of the stream and as they pass through smaller vessels they elongate.

End: They are broken up in the spleen and also perhaps in the liver.

WHITE.

1. Less numerous.
2. Globular in form, although they change form on account of ameboid movement; average diameter 1-3000 of an inch, varying.
3. Granular and nucleated.

4. Lighter than the liquor sanguinis or plasma.

5. Consists of protoplasm, undifferentiated corpuscles and contains a few minute globules of oil.

6. Origin: Formed, first, in the spleen; more of these bodies are found in the splenic vein than in the splenic artery, and are found in enlarged spleen in leucocythemia; second, in lymphatic glands bodies like the leucocytes are found; third, in the red marrow of bone and possibly in areolar tissue generally.

7. Function: They form the red blood corpuscles and have some other function in the tissues as migratory cells. They pass along the lateral part of the stream, clinging to the capillary walls and sometimes pass through.

8. End: Some form red blood corpuscles, others escape into the tissues, chiefly in connection with the lymph.

Water swells up the red corpuscles and dissolves out the hæmoglobin which is seen to be of a darker shade than when found in the corpuscles. Acetic acid seems to have a similar effect, and in the case of the leucocytes it makes the nuclei distinct. Solution of syrup of sodium chloride shrivels up the red corpuscles. These red corpuscles in all the mammals are:

1. Circular, except the camel family which are thin and oval.

2. Non-nucleated.

3. Bi-concave and sometimes flat and bi-convex.

The largest red blood corpuscles are found in the amphibians, in which animals and all other non-mammals they are oval and non-nucleated. In one cubic m. m. of human blood there are 5,000,000 red blood corpuscles in the male and 4,500,000 in the female, to about 15,000 white; giving us the proportion of the red to the white of 330 to 1. According to Welcker 335 to 1; Molesshot, 357 to 1. The earliest red corpuscles appear as little colored masses within the embryonic cells, each having a nucleus. At a later period we find nucleated red corpuscles formed in the liver. These nucleated red blood corpuscles found in the liver are gradually replaced by non-nucleated discs before the intra-uterine life is terminated.

Coagulation of the Blood:—By this is meant the change that takes place when the blood is removed from the living vessel, that is, its separation into a solid part (the clot) and a fluid part (the serum). If some blood is drawn into a vessel almost immediately a film appears upon the surface and in a few minutes the blood has become a semi-solid mass of the same volume as the original blood when drawn. In a short time this mass begins to shrink and after some hours a firm red clot is found floating in a pale yellowized fluid (the serum). The solid matter, as it shrinks, presses out the fluid. The shrinking is most marked in the center of the clot. The upper surface is consequently concave and the clot itself is said to be cup-shaped. There are three stages through which blood passes before the formation of a perfect clot:

1. A stage called viscid.

2. Jelly or gelatinous.

3. Contraction of the clot and separation of serum.

The first stage, the viscid, is short. usually requiring only a few minutes. In cold weather a considerable quantity of blood may take a much longer time. During this stage if the blood is con-

tained in deep vessels the first stage may occupy from a few minutes to some hours. The second stage may be completed in a few minutes or may take several hours if a large quantity of blood is kept cool and motionless. The third stage begins as soon as ten minutes after shedding or as late as several hours after shedding. During the formation of the clot under ordinary circumstances the corpuscles become entangled in the mesh-work of fibrin so that the jelly mass has throughout a dark color. The clot then consists of fibrin, an albumenoid substance found in fine fibrils amongst which are entangled the corpuscles. The serum, or fluid, is a very pale yellowish fluid with an alkaline reaction, consisting principally of water, about 90 p. c., and containing:

1. A small quantity of albumin, from 1 to 5 p. c. which coagulates on boiling.
2. Certain nitrogenous substances as follows: creatin, urea, uric acid, etc.
3. Certain fatty substances.
4. Salts, consisting of the chlorides, sulphates, phosphates and carbonates of alkalies, etc.

The Causes of Coagulation: Coagulation is due to the formation of fibrin. This does not exist in the blood in its normal condition, but is formed by the union of two substances—fibrinogen and fibrinoplastin or paraglobulin, probably under the influence of a ferment. Fibrinogen exists in the liquor sanguinis and fibrinoplastin exists in the corpuscles, some physiologists say in the red and some in the white. It is not clearly known why these two substances do not unite and form fibrin while the blood is in circulation in the healthy vessels. One explanation is that the paraglobulin and the ferment are both contained in the white corpuscles and as long as these corpuscles remain intact the paraglobulin cannot escape to unite with the fibrinogen. If the white corpuscles undergo disintegration from any cause the paraglobulin and ferment escape. The paraglobulin unites with the fibrinogen and fibrin is formed as a result. This disintegration of the white corpuscles always takes place when removed from the vessels and also when the epithelial lining of the vessels is either injured or destroyed. In the former case we have coagulation when the blood is shed and in the latter case coagulation within the vessels. In the vascular coagulation the process is called thrombosis.

The blood may be regarded as a tissue made up of living elements requiring constant assimilation and elimination for the maintenance of life conditions. Coagulation is the result of certain chemical changes concomitant with the death of the blood, that is, while the blood lives no such changes take place normally. Constant chemical interchange between the blood and the walls of the vessels is required to sustain the life conditions of the blood. The solid formation found in the clot and separation of the liquid proteid found in the serum is perfectly in line with what we find in other tissues, for example, soft contractile tissue at its death undergoes a change almost identical with coagulation. The only thing that we know definitely in blood nutrition is that there is a very close relation constantly demanded between the blood and the membrane lining the vessel wall (intima). We get most of our knowledge of this subject

by studying the conditions under which the blood clots in the living vessel. Coagulation does not take place while the relation of the vessel and the blood flow remains perfect, but it follows a lesion of the delicate membranes lining the vessels, whether the result of injury or malnutrition.

During the first stages of inflamation on the account of the arrest of the flow of blood the walls of the small vessels suffer from defective nutrition, allowing certain elements to escape, while the discs adhere together and the plasma coagulates in them. We find the same thing in the larger vessels when inflamation of the lining membrane destroys its capacity of keeping up the relation between the vessel walls and the blood. On the valves of the left side of the heart and in the arteries where the delicate relation of vessel wall and blood is subject to great strain it is common to find slight injuries covered with small clots. Foreign substances such as a thread introduced into the circulation of the blood forms a clot, the white corpuscles collecting on the thread. The time necessary to introduce intravascular clotting is long for the blood current has been stopped several hours without intravascular coagulation, due to the fact that so long as the relation of the vessel wall and blood is maintained the blood remains fluid. In fact, the tissues die before the blood clots in the vessels. Even after death the tissues live and the blood continues fluid as long as the vessel wall can nourish itself and continue to live. In cold blooded animals the tissues live longer, for example, tne heart of a tortoise will live for two days or more after removal from the body. Certain chemical changes must take place within the blood to preserve its integrity. The cessation of of these changes results in certain new products among which we find fibrin. When the blood is removed from the vessels, or the relation between the blood and the vessel wall is injured the production of fibrin follows, either because the blood elements are destroyed or because of the impossibility of reintegration, the fibrin appearing as a death element in the case of intravascular clotting. This death element is removed by the vigorous action of the other live elements in the body, whereas in shed blood these life elements cease to exert an influence. Coagulation can be prevented by whipping-fresh blood with a bundle of twigs the fibrin forming on the roads. Coagulation is accelerated:

1. By the free access of oxygen.
2. By rest.
3. By warmth. The formation of the fibrin generators and the action of the ferment seems to go on more rapidly at 38 to 40 degrees C. than at any other temperature
4. By contract with a foreign body.
5. By contract with rough surfaces.
6. In flat vessels much more quickly than in deep narrow vessels; the greater the surface in contact with the vessel or air the more rapid the chemical changes inducing fibrin formation.
7. It is accelerated in a vaccunm.

Coagulation is retarded:

1. By absent of oxygen.
2. Temperature below zero and above 60 degrees C.
3. By saturation of the blood with $CO^2$.
4. Addition of neutral bases of the alaklies.

5. Addition of acetic acid until slight reaction is obtained.

6. Addition of solution of potassium oxalate.

7. Addition of albumose to the blood.

8. Addition of a large quantity of water.

9. Addition of egg albumin, syrup or glycerine.

If coagulation be delayed, for example, by surrounding the vessel containing the blood with ice, the white corpuscles being lighter than the blood plasma will rise to the top while the red corpuscles being heavier will sink to the bottom. When the ice is removed coagulation will take place, resulting in a clot which will be red below and of a pale straw color above. This pale upper surface is called the buffy coat and the blood is said to be buffed. Inflamatory blood and the blood of some animals, for example the horse, always coagnlates slowly. Hence in these the buffy coat is always found.

The quantity of blood in the whole vascular system is calculated to be about 1-12 to 1-13 of the body weight. A volume of blood equal to that in the body passes through the heart in a period occupied by 27 to 30 heart beats. For example, in a man weighing 140 lbs. we find about 11 lbs. of blood or 5,280 cc. Each heart beat ejects about 173 ccm. giving us about 30 beats during which the whole volume of blood passes through the heart. Taking pulse at normal, 72 per minute, 30 heart beats will occupy about 25 seconds. So that an amount of blood equal to the whole volume of the body passes through the heart twice every minute. In various animals great variation has been found. In different animals, and also this is true in men,) the variation is more slight in man) a sudden drain on the water of the blood by great activity of the excretory system, for example, in sweating or a sudden addition to the water of the blood, these are quickly compensated for by the passage of water from the tissues to the blood and vice versa. In this way the tissues constantly strive to keep up the average composition of the blood. Normally the blood is distributed as follows: In four parts; one part in the heart, lungs, large arteries and veins; one part in the liver; one part in the skeletal muscles and one part in the other organs. In the heart and great blood vessels blood is simply in transit without undergoing any great changes. In the lungs also it is limited to respiratory changes while in passing through the liver and skeletal muscles it undergoes great changes.

THE PHYSIOLOGY OF THE TISSUE OF THE BODY:—In the body there are many tissues which are of an advantage to the organism as a whole, rather on account of physical than of vital properties. In these tissues the corpuscles nourish themselves, possess irritability and capability of reproducing their like. The chief advantage of these tissues to the organism arises from their physiological characteristics, which are due in general to intercorpuscular substances. For example, areolar tissue, mechanically connects different tissues and different organs; elastic tissue brings back to their original shape or position parts which have been disturbed or moved; adipose tissue acts as a padding to various parts and being a bad conductor of heat assists in preventing the loss of heat by radiation. The strong non-elastic tendons connect

muscles with bones and ligaments with similar properties bind bones together at joints while the bones and cartilages form an elastic frame work on which the softer parts are moulded. They also give support and protection as well as forming levers on which the muscle exerts its power. The properties of these tissues are so closely connected with the structure that they cannot be separated from, and are considered along with the histology of these tissues. In the case of epithelium in which the intercorpuscular substance is exceedingly limited in amount, there is one variety, namely, that covering the external surface of the body, the epidermis, which affords a certain amount of mechanical protection. The superficial corpuscles becoming of a horny and hard nature while other parts are so closely connected with the function of secretion and excretion that their physiology can best be considered in in connection with those other organs of the body in which they are found With regard to cilliated epithelium it may be stated in general that as each cillium rapidly and alternately bends and recovers itself again and as all of them move in the same direction, that movement being generally toward an external orifice, the general effect is to drive the fluids and small solids along the surface of the mucous membrane until they are expelled from the body. Aside from these tissues there are two tissues—muscular and nervous tissues—the vital phenomena manifested by them being so striking, so frequently exhibited and of so much advantage to the organism they must be considered separately. In both of these cases, the original more or less spherical shape of the corpuscles has been lost in most cases. As to the structure that exists to such a large extent that it is difficult, if not impossible, to individualize these corpuscles because they have become fused together.

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# Physiology of Muscular Tissue.

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It is to the muscular tissue that the function of effecting the various movements of the body and its several parts has been delegated. The most striking property of muscle is its contractility, that is, its corpuscles manifest their irritability by contracting or by temporary alteration of form when stimulated. Like all other living corpuscles in the body, the muscles take up and assimilate food from the blood, absorb oxygen and excrete carbonic acid and other waste products. Being a very active tissue it is well supplied with blood vessels. Muscles which remain idle diminish in size, while those which make great efforts increase in size.

Here we have the relation between function and activity in the case of muscle. Evidently their functional activity promotes the proper nutrition of the muscle. There must, however, be intervals for rest, otherwise the muscle will become injured by excessive fatigue. During, or for a short time after the contraction of a muscle its blood vessels are dilated so that more blood passes to the muscle and to this must be attributed the fact that functional activity pro-

motes the growth and activity of the muscle. Certain nerve centers are called trophic nerve centers being in some way concerned in the nutrition of muscles. When they are destroyed the muscles rapidly waste. Thus in certain forms of paralysis the muscles gradually waste away owing to their inactivity. In other forms, for example infantile paralysis, the wasting away is far too rapid to be accounted for in this way. It is supposed the trophic centers are located in the anterior cornua of the grey matter of the spinal cord.

Muscular Irritability is the vital property in virtue of which muscle has the power of responding to a stimulus. The response in case of muscle is a contraction or alteration of form, hence muscle is said to be contractile or possess contractility because it evidences possession of irritibility by contraction when stimulated. When a muscle is stimulated it is seen for a time to become shorter and thicker, that is, to contract and then relax or return to its original form. The same result will be observed if a single muscular fiber be stimulated under the microscope, the contraction passing like a wave along the fiber from the point of stimulation. At the same time the light parts of the fiber are seen to become dark, causing the dark and transverse striæ to appear light. While both dark and light parts become shorter and thicker, the change is most marked in the light portions of the fiber. Muscular contraction is an alteration of form, not bulk, as may be shown by causing a muscle to contract inside a vessel shaped like a specific gravity bottle and filled with water. If the contraction were a dimunition of volume the level of the water in the capillary neck would fall, but this is not the case. Foster says that muscle does slightly diminish in bulk during contraction. In the body muscles are probably always stimulated to contract by nervous impulses, but any agent which will rouse up dormant irritibility will act as a stimulus; for example, mechanical, chemical, thermal or electrical influences. To be effective a stimulus must have a definite duration, a certain intensity and must act abruptly or suddenly. Contractility is inherent in muscles. It is a property of muscular fibers themselves, and it exists and is quite capable of being manifested altogether apart from the nerves which are merely the medium through which, in the body, nervous impulses reach the muscles and arouse their activity. The truth of this may be demonstrated by stimulating a single muscular fiber, freed from all nervous connection, under the microscope when contraction will be observed to take place; or by putting a frog under the influence of curare which poisons the end-plates of the nerves in the muscles. If in an animal so treated a stimulus is applied to a nerve passing to any muscle, no contraction follows, but if the stimulus be made to act on the muscle itself contraction at once occurs. The instrument used in studying muscular contractions are, the revolving cylinder, chronograph, myograph, frog muscle plate, induction coil, keys, commutator and electrodes. To study the phases of a single muscular contraction the muscle is placed on the muscle plate and its tendon attached to the lever. The muscle or its nerve is brought into contact with the electrodes and there is

introduced into the circuit from the battery where a signalling apparatus will indicate on the revolving cylinder the instant that the stimulus reaches the muscle, and on its being moved by the shock the cylinder is made to rotate and a single electric shock is transmitted. The muscle shortens and then returns to its original form. This, of course, moves the lever and a tracing, a muscle curve as it is called, is drawn on the smoked paper covering the cylinder. By means of this arrangement it is seen that the muscle curve produced by a single contraction is the result of a single momentary stimulus which consists of three parts:

1. The period between the reception of the stimulus and the commencement of the shortening, during which there is no apparent change in the muscle. This lasts about 1-100 of a second and is called the period of latent stimulation or contraction.

2. The period of shortening during which the muscle shortens or, strictly speaking, contracts, represented by the ascent of the curve.

3. The period of relaxation, during which the muscle returns to its original length, represented by the descent of the curve. It occupies rather longer time than the second. The relaxation is the result of active changes in the muscle, just as the shortening, and not a mere passive recoil.

By repeating the stimulus again and again as soon as one contraction is over, a series of identical curves may be obtained. After a time, however, the muscle becomes fatigued and then the curve does not rise so high and the period of relaxation is more prolonged. If the stimuli are sent to the muscle so rapidly that the second contraction begins before the first is completed and the third before the second shortening is finished, then the amount of shortening resulting from the action of successive stimuli are added together and the muscle rushes into a state of tetanus; that is, a state of extreme and persistent contraction which continues until fatigue comes or the stimuli cease, when it slowly relaxes. What appears to be a single muscular contraction is really a number of contractions fused together, the result of numerous nervous impressions which reach the muscle at the rate of about 19 per second. A contracting muscle is in a state, therefore, of vibration and like other vibrating bodies it produces sounds which can be heard by the stethoscope placed over a contracting muscle. Various circumstances influence muscular contraction:

1. The length of the stimulus.
2. The load to be lifted.
3. The fatigue.
4. The degree of irritability.

Physical Properties of Muscle and the Changes that Occur During Contraction: A muscle when relaxed is soft; when contracted, firm and hard. After death, sooner or later, the muscle becomes quite hard and rigid. This is not due to contraction, but to coagulation of the muscle substance. A muscle can be very easily stretched, and when the stretching force is removed it returns exactly and rapidly to its original shape, or as it is technically expressed, the elasticity is slight but perfect. This property of muscle elasticity is of advantage, first, in assisting to restore muscles, after compression, to their or-

iginal length, and second, in effecting the economizing of energy. A muscle is more easily stretched when contracted than when relaxed.

Chemical Properties of Muscles and the Changes Which Occur in Them During Contraction: Living muscle at rest is neutral or slightly alkaline in reaction, but when contracted it becomes acid. This acid is known as sarcolactic acid. Dead muscle is also acid in reaction. If the muscle removed from the body of a recently killed frog is freed from blood, kept at a low temperature and subjected to pressure there will be expressed a neutral fluid or a slightly alkaline, gelatinous fluid called the muscle plasma. The solid residue consists of nuclei, sarcolema, fats, etc., derived from lymphatics mixed with muscular tissue. This muscle plasma, at the ordinary temperature of the atmosphere, soon coagulates, that is, becomes jelly, the reaction being acid. The jelly that is thus formed soon separates into:

1. The solid part, the muscle clot or myosin plasma.

2. A fluid part, the myosin serum.

The muscle clot consists of an albuminous substance—myosin, soluble in sodium chloride, or other dilute saline solutions and also in dilute acids. A stronger acid solution, for example, 1 p. c. of hydrochloric acid changes myosin into another albuminoid substance, syntonin, insoluble in a solution of sodium chloride and also insoluble in sulphate of magnesia. Muscle serum contains, as follows:

1. Serum albumin and other proteids may be coagulated by heat when the fluids are neutralized.

2. Nitrogenous extractives— creatin, xanthin, taurin, lecithin, urea, uric acid etc.

3. Salts, especially those of phosphates of the alkalies and alkaline earths, chloride of potassium, small quantities of sodium chloride and sulphates of the alkalies.

4. Water forms about 3-4 of the weight of the muscle; from 74 to 80 p. c.

5. Gases—$CO^2$, a little N. and no free O. In 100 parts of muscle there has been found $CO^2$ 14.1: N., 4.9; O., 09; total 19.39. It is probable this much of the $CO^2$ may have arisen from decomposition. In addition to these the following substances have been found also in muscle serum:

1. Non-nitrogenous substances, grape sugar and animal starch (glycogen) specially abundant in embryonic muscle, inosite (muscle sugar) in cardiac muscle.

2. Acids, small quantities of volatile acids, acetic. butyric and formic, the two lactic acids, the sarcolactic and ethylene particularly after muscle is working.

3. Several ferments, for example, pepsin, ptyalin and special muscle ferment (myosin) and a red coloring matter almost identical with haemoglobin called myohaematin. This coloring matter is said to exist in the iso-trophic parts of the fibre. Our knowledge of the chemistry of muscle is chiefly derived from the investigations of a German, Kuhne, on the muscles of frogs. Halliburton has made many recent additions to our knowledge in regard to the muscles of the warm blooded animals, by experiments on the horse and rabbit. He obtained plasma from the muscles of a rabbit by washing out the blood from the vessels by a .6 p. c. of sodium chloride at 5 ° C. and placing the muscle in a freezing mixture of ice and salt at a tem-

perature of 12° C. and then subjecting the muscle to pressure. The result was a yellow viscous fluid slightly alkaline in reaction which forms into a solid jelly in from one to two hours at a temperature of 40° C. Halliburton found coagulation took place in from 20 to 30 minutes. He found a solution of neutral salts prevented coagulation of the plasma and that the dilution of salted muscle plasma caused or induced coagulation. The separation of plasma into clot and salted muscle serum does not take place at 0° C., but occurs most readily at the temperature of the body and is hastened by the addition of a ferment prepared from the muscle as Schmidt prepared his blood ferment. The proteids of muscle plasma are five in number.

1. Paramyosinogen, which coagulated by heat at 47° C.

2. Myosinogen, found to coagulate at 56° C.

3. Myoglobulin, differing from serum globulin in its coagulation temperature, that of myoglobulin being 63° C.

4. Albumin, the same as serum albumin, coagulates at 73° C.

5. Myoalbumose, almost identical with muscle ferment (related to myosinogen.)

The first two of these form the myosin clot and the other three the muscle serum. The first three are globuline. When the muscle becomes acid by the formation of lactic acid, as in cadaveric acidity, the pepsin it contains acts, and at a proper temperature of 35 to 40° C. Albumoses and peptones are found by a process of self digestion. Halliburton supposed the passing away of rigor mortis, which was due to the reconversion of myosin into myosinogen, may be the first stage in this process of self digestion. In regard to muscle ferment Halliburton concludes:

1. By keeping muscle under alcohol for some months most of the proteids are coagulated, water however will extract proteids from the alcoholic precipitates.

2. This albumose has the property of a ferment in causing a coagulation of muscle plasma.

3. This myosin ferment does not hasten coagulation of muscle plasma nor does the fibrin ferment hasten coagulation of muscular plasma.

4. The fluid that escapes from the muscle hastens very markedly the coagulation of salted muscle plasma. This is due to the proteid substance called myosinogen which enters into heat coagulation at a temperature of from 75 to 80° C. whereas the activity of myosinogen is not destroyed till after temperature of 100° C.

Chemical Changes During Contraction:—These are not settled among physiologists, but the following are accepted:

1. The amount of O. used by muscle is increased.

2. The amount of $CO^2$ is more than proportionally increased.

3. The amount of N. waste is not increased.

4. The muscle becomes acid in reaction.

5. Gaseous extractives are diminished. the alcohols are increased. One of the explanations is this: The muscle containing certain carbonaceous matters, which when the muscle is acting acts as a fuel, being oxidized by the O. in the blood, the results being movement and heat. It is not the albuminoid matter of the muscle substance that is used up but the caabonaceous material found in the muscle, hence, where there is no increase in nitrogenous waste there is an increase

of carbonaceous waste. One of the products of this chemical change is the sarcolactic acids formed from the carbonaceous material lodged in the muscle. It is a question if the explanation just given is sufficient to account for the changes which take place. It may be noticed that the increased production of $CO_2$ is not accounted for by the oxidation of carbonaceous materials by the O. of the blood for although it is true more O is used by muscles when working it is also true that the increased proportion of $CO^2$ given off is much greater than can be accounted for by the increased consumption of O. In addition to this a living muscle placed in an atmosphere free from O. will continue to produce $CO^2$ as long as it is living.

As muscle itself contains no free O. and the surrounding atmosphere is destitute of this gas it is very clear that $CO_2$ can not be the result of the direct oxidation of carbonaceous matter present in the muscle, but it must be a result of the splitting up of some bodies which contain $CO_2$. It may also be said that whether the acid reaction of the muscle that has been actively working is due the sarcolactic acid or not, it is certainly not due to the $CO^2$. for the red dying on the blue litmus paper which it produces is permanent. One result of this chemical activity is the increased production of heat; this is shown by the fact that blood flowing from a contracted muscle is warmer than from a muscle at rest. The same fact can be proven by putting the bulb of a thermometer into the muscle and causing contraction when the mercury will be seen to rise. Like all other living corpuscles muscle is at all times the seat of chemical changes and it is thus constantly a source of heat. As the chemical changes during contraction are more active than the amount of heat elaborated at that time is increased. The heat produced by any contraction is in inverse proportion to the amount of work performed by the contraction.

The Electric Phenomena of Muscle and the Changes During Contraction: With suitable apparatus it can be demonstrated that if from the body of a frog a living muscle is taken an electric current can be obtained. The current from a single muscle is very feeble and, in order that it may be evidenced the muscle must be placed upon the non-polarizable electrodes in connection with a very sensible galvonometer. If this is done so that the longitudinal surface of the muscle is in contact with one electrode and the transverse section in contact with the other electrode the needle of the galvonemeter is deflected and remains so as long as the circuit is closed and while the muscle is alive and at rest. This is due to the passage of an electric current and the direction of the current is from the longitudinal surface of the muscle through the galvonometer to the transverse section of the muscle. The circuit is presumed to be completed by the passage of the current inside of the muscle from the transverse to the longitudinal sections. The strongest current is obtained when one electrode is in contact with the longitudinal surface of the muscle at a transverse line which divides the longitudinal surface into two equal parts called the equator of the muscle, while the other electrode touches the center of the end of the muscle or any other transverse section. In this way it can be shown:

1. That the equator is positive to any other longitudinal surface.

2. Any point on the longitudinal surface is positive to any point most distant from the equator (that is transverse). The center of the transverse section or end of the muscle is negative to any other point on the transverse section or end which is most distant from the center.

3. When the electrodes are in contact with two points on the longitudinal surface equi-distant from the equator, no currents are obtained.

4. When the electrodes are in contact with corresponding points on the opposite longitudinal surface, no currents result.

5. When the electrodes are in contact with points on the transverse section or ends equi-distant from the center, no currents are obtained.

6. When the electrodes are in contact with corresponding points, that is with points equi-distant from the respective centers of opposite and transverse sections, no currents result.

It is a disputed point whether the electric phenomena are natural manifestations of living uninjured muscles, or whether they result from chemical changes which follow the injury done to the muscle in removing it from the body or making transverse sections of it.

Negative Variations:—We have seen the needle of the galvonometer remains deflected as long as the muscle is alive and in contact with the electrodes. One other condition, however, is necessary that the muscle be at rest. If the muscle is stimulated and made to contract the needle will swing backward to its original position. Whether this is due to the cessation of the original current or to the development of the current in an opposite direction is uncertain. One thing is certain some change is produced on the electrical state of the muscle and to the change is applied the name negative variation. This negative variation commences in the muscle at the very moment of stimulation and is said to last only 1-300 part of a second. It occupied the first period or part of latent stimulation and is over before the muscle begins to contract. When a stimulus acts on a muscle it may be regarded as setting up certain molecular changes. Negative variation is the change produced in muscle in contact with a galvonometer when at rest. As a result of these changes there is an immediate change in the electrical condition of the muscles while after the interval including the period of latent stimulation, the muscle becomes shorter, thicker, firmer and more easily stretched. If the muscle is carefully examined certain chemical changes take place, these changes manifest themselves in increased production of O in more than proportional increase of elimination of $CO_2$ and development of acid reaction. At the same time the gaseous extractives of muscle are diminished the alcohol extractives of muscle increase. Energy is manifested partly as mechanical work and partly as heat. If a muscle receives a rapid succession of stimuli it is thrown into a tetanus state and being in a state of vibration produces a muscle sound. Coincident with this contraction of the muscle the supply of blood to it is increased by dilatation of the blood vessels, this condition continuing for a short time after the contraction ceases.

Muscular Tonicity:—By this is meant that slightly contracted state in which some (the muscular fibres of arteries) and possibly all the muscles are maintained during life. It appears to depend upon the connection of the muscles with the nervous system. In the living being the muscles are more or less stretched between their attachments. They are said to be in a state of tension or tonicity. Various questions have arisen in regard to muscular tonicity—one of these is whether muscular tonus is under the influence of the nervous systems. Brondgreat divided the spinal cord of a frog below the medulla oblongata and then divided the nerves of the leg on one side; on fixing the frog firmly on a board he found the muscles of the leg on the side of the opreation loose and the leg longer than the other. He concluded that the spinal cord furnished the muscles with permanent inervation. Heidenhaim stretched a muscle by weights and found that it does not elongate after a section of the nerve supplying it. The probability is that both inervation and the blood circulation have an equal influence on muscular tonicity by affection of the nutrition of the tissue. If a muscle be struck across the fibres, perpendicular to the direction of its fibres, with a blunt instrument, the whole muscle gives a single contraction and then relaxes, but the part of the muscle which receives the blow remains contracted for some little time. This phenomenon is called by Schiff Idio-muscular contraction. It will often follow such a stimulus as that produced by a blunt instrument when no other stimuli cause contraction. It is called myodemia on the appearance of small tumors, on tapping the skin over the chest in consumption and other diseases. These little tumors are due to the contraction of the muscle fibres in the skin.

Reproduction of Muscle—Muscular corpuscles themselves appear to have lost the power of reproducing their like, for if a muscle be cut across, the ends become united again not by muscular, but by fibrous tissue. The increased size of the uterine walls which occur during pregnancy is accounted for partly, by growth (enlargement) of the original muscular fibres, and partly by the formation of new fibres from the corpuscles. The striped muscles seem to increase in size in a similar way.

Death of Muscles:—Muscle completely deprived of nourishment, either by ligature of the blood vessels, by removal from the body, or by cessation of the circulation which occurs in the case of general death passes after an interval, into a condition known as rigor mortis, cadaveric rigidity. The length of time which elapses between the stoppage of the blood supply and the beginning of rigor mortis is much longer in the cold than in warm blooded animals. In the latter also the time of the appearance of the rigidity is influenced by the circumstances under which death occurs. Often in diseases which have gradually exhausted the strength, rigor mortis soon comes on, while in cases where death has come suddenly upon a system full of vigor, its appearance is delayed. During the interval before the coming on of the rigor the muscles retain their irritability. They are still alive and will contract when stimulated. The irrability gradually lessens; it completely dissapears as the muscle somewhat suddenly enters into a

rigid, opaque, unelastic condition. At the same time the muscle becomes acid in reaction, and a quantity of $CO_2$ is given off. The duration of cadaveric rigidity varies. In cases where it soon appears, it rapidly disappears; while it remains longer, and is more marked when some time has elapsed before its development. As it passes off, the muscles become soft and diffluent—a result of putrefaction. There is, of course, no return of irritability, for the muscle is dead and irritability is a vital property. The exact nature of rigor mortis is not definitely understood. It is certainly not a center action of the muscle as it does not appear until their irritability is lost. The muscular substance (myosin) becomes coagulated which follows the cessation of the blood supply. In the human subject rigor mortis successively appears in the muscles of the jaws, neck and upper and lower limbs, and it disappears from the parts in the same order. The length of the interval between general death and rigor mortis varies from a few minutes to several hours or several days. The entire disappearance of irrtiability coincides with complete establishment of cadaveric rigidity. This lasts for a period of one to four days. After the cadaveric rigidity disappears, putrefaction insues. Muscular rigidity may also be caused by heat at 40° C. The muscles of a frog become rigid at 53° C. The muscles of some birds become rigid. This rigidity differs from rigor mortis as it is due to coagulation of the other proteids besides myosin produced by heat. Muscular rigidity may also be produced by the injection into the vessels of 2 p. c. solutions of hydrochloric or lactic acid. This rigidity will yield to the injection of 15 per cent. solution of amonium chloride.

Unstriped Muscle:—This muscle as far as it is understood in its physical. chemical and other properties resembles the striped muscle. When stimulated, either directly by mechanical or the malstimuli involuntary muscle contracts. The contraction is preceded by a long latent period; the period of latent stimulation being very much longer than in striated muscle. The contraction takes place slowly and lasts some time, and the period of relaxation is also prolonged. The general character of the contraction may be seen in the movement of the intestine of a recently killed warm blooded animal. In the œsophagus, intestine, etc. the muscular fibres are arranged in an outer longitudinal and an inner circular set. When stimulated at one point, the fibres at that point contract, and a wave of contraction slowly passes along the tube effecting both longitudinal and circular fibres. This constitutes a peristaltic action or wave. Marey has shown that the contraction of non-striated muscles is not made up of a series of smaller contractions as in striated muscles, because most of the former are under the control of the will, while the latter, as a rule are not. There are, however, many exceptions to this general statement: thus, the heart which acts involuntarily is composed of a variety of striped muscles, and many of the striped muscles act frequently. Health and disease without any prompting of the will or from the will. Probably the reason for the employment of one kind rather than the other for any particular purpose will be found in the fact, that the action of the one is prompt and rapid while that of the other is slow and prolonged.

Contractile Corpuscles Other Than Muscles:—Besides the corpuscles of muscles, other corpuscles manifest contractility, indeed, in the eatliest stages of their existence all corpuscles are probably contractile. The lash-like movement of the tail of the spermatozoon, the amoeboid movements of the white blood corpuscles, lymph corpuscles, migratory cells and the vibrations of the ciliated epithelium are all manifestations of contractility. The movement of the cilia continues for some time after death of the body if the surface be kept moist. This appears to be independent of the nervous system. Its exact causation is obscure. When the energy which we call nerve force reaches a muscle fibre, it acts on the motor-plate, probably setting up molecular changes which are propagated to the contractile substance of the muscle. The molecular changes pass quickly to each end of the fibre and they are the source of the action current or negative variation. This wave of negative variation seems due to the polarization hypothetical electro-motive molecules. The short period during which the action current passes through the fibre does not exceed 1-300 part of a a second and for the longer period 1-100 part of a second the fibre is apparently inactive. This is the period of latent stimulation and during this period molecular phenomena occur which precede contraction. Probably during this latent period energy is liberated as heat, but a part of muscular heat evolved during the period of active contraction. At the end of the latent period the fibre contracts, and during the contraction of a number of fibres, the muscle sound is produced. The muscle fibre then relaxes and the katabolic products of nervous stimuli are quickly removed and the muscle substance is built up anew. Another result of the molecular disturbance excited by the nervous stimulus is the increased production of dioxide and probably other waste products and the increased consumption of oxygen. These physiological changes of a muscle illustrate in a striking way, anabolic and vatabolic proceses occuring in living matter. Many of the processes occuring in other tissues viz.: the glands, and sense organs and even in the central nervous organism are analogous to those of muscular contraction.

# Physiology of Nervous Tissue.

Under nervous tissues are included not only nerve fibres but also the nerve centres, with one of which each nerve fibre is connected by one of its extremities. Further, the only extremity of the nerve fibre, in many cases at least terminate in some special structure, termed an end organ, and these nerve organs may be considered in connection with nervous tissues But many of these end organs are affected by certain special stimuli, and different nerve centers have different functions allotted to them. It will therefore, be convenient here to discuss only these phenomena of nervous action which are exhibited more or less by all nerve

centres and all nerve fibres. Certain special effects will be explained concerning nervous action with the physiology of the various organs, and of the central nervous system With the latter also it will be convenient to consider the function of these specialized structures and organs, through which certain special agents (odors, light, sound etc,) are able to stimulate nerve fibres.

NERVOUS TISSUE:—In the body there are two nervous systems which are, however, closely related to one another at many points. (1) The cerebro-spinal, consisting of brain and spinal cord, cranial and spinal nerves in connection principally with the integument, organs of special senses, the voluntary muscles, etc. (2) The sympathetic, consisting of small nerve centres or ganglia and nerve fibres in connection with them the greater number of fibres joined by fibres form a chain on each side of the vertebral column. The sympathetic is chiefly in relation with the blood vessels and viscera. The nervous system in man consists essentially of three parts. (1) Nerve centres, (2) terminal organs and (3) nerves or nerve fibres joining together the centres and terminal organs. A nerve center always contains nerve corpuscles which are supported by a delicate neuroglia. Each nerve corpuscle is nucleated, destitute of a cell wall and has a varying number of branches or poles one of which is continuous with a nerve fibre (axis cylinder.) The different varieties of nerve corpuscles are (1) bipolar, in the ganglia on posterior roots of spinal nerves, (2) tripolar or pyramidal in the gray matter of the surface of the cerebral hemispheres, (3) multipolar in the gray matter of the spinal cord, (4) the pear or flask shaped cells called also the tadpole cells, in the gray mater of the cerebellum. The nerve fibres are of two kinds. (1) White or medullated found chiefly in the cebro-spinal system and (2) gray non-medullated in the sympathetic system and in the olfactory nerve A nerve or nervous cord as found in the body is composed of an outer sheath from which partitions pass in separating different bundles or faciculi of nervous fibres. Each little bundle has, also a separate sheath of its own composed of nerve fibres. A white or medullated nerve fibre is a narrow band varying in diameter from 1-12000 to 1-15000 part of an inch having a double contour and a slightly sinuous outline consisting of (1) a delicate, transparent outer sheath, the lining membrane or primitive sheath, (2) on the deep surface of this are nuclei (3)contained within the sheath is semi-fluid matter which after death or under the influence of reagents (acetic acids) is found to be divided into two parts (a) a central albuminous thread, the axis cylinder. This is the essential conducting part of the nerve from the extremity (central) where it is continuous with the nerve corpuesle. It passes continuously along the course of a nerve and it is only when close to its peripheral termination that it breaks up into fine branches. Under high power of the microscope longitudinal striae may be seen, (b) surrounding the axis cylinder is a less dense substance known as the medullary sheath or white substance of Schwann. This contains a large proportion of protagon, a substance in which both nitrogen and phosphorous are constituents and which yield a large amount of fatty matter. When it is stained black with osmic acid

the white substance is seen to be interrupted at regular intervals, these interruptions being termed the nodes of Ranvier. The portions of nerve between the nodes being called internodes. A single nucleus on the surface of the primitive sheath is found in each node. The non-medullated or gray nerve fibres are flat, narrow bands with numerous nerve nuclei. It is a question whether there is a fine outer sheath or not. There is no white substance of Schwann and the fibres often branch off and unite with neighboring fibres. These are found in the sympathetic and olfactory nerves.

NUTRITION OF NERVOUS TISSUE—Like the corpuscles of muscles and other tis sues, the nerve cells or corpuscles existing in the nerve centers receive their supply of nutriment and oxygen directly from the circulating blood. The nerve fibres which consist essentially of corpuscles are also said to be nourished by the blood through the nodes of Ranvier. Whether this is correct is uncertain; but it is certain that the nutriment of the nerve fibres depends in a very marked degree upon their connection with certain nerve centres, called trophic nerve centres. e. g. If the sciatic nerve be cut through it will be found that the portion separated from the spinal cord may soon begin to lose its irritability, the loss of irritability beginning at the cut end and passing gradually down the nerve. This centrifugal loss of sensibility according to which the change in irritability progresses centrifugally along the motor nerve is known as the Ritter-Vallis Law. Fatty degeneration with the breaking up of the axis cylinder follows and then changes pursue the same course as the loss of irritability, namely, from the cut end of the separated portion they pass along the nerve down even to its very finest branches. This is the law of Waller. Opposed to this is the fact that the portion of the nerve remaining in connection with the spinal cord is uneffected except from the place of section, up to the 1st node of Ranvier, where similar changes to those already described take place. The difference is seen to be very marked and the explanation is that the one portion of the nerve has been separated from, whereas, the other has remainedin connection with its trophic nerve center. Remembering that the trophic nerve centers of the motor fibres are the cord and those of the sensory fibre is the ganglia of the posterior root of the nerves the following actions will be understood. (1) Section of the anterior (motor) root. The portion in connection with the cord remains unchanged. The separated portion and the motor fibres in the nerve trunk degenerate (2) Section of posterior (sensory) root between the ganglia and cord. The portion of the root in connection with the cord, separated from the ganglia degenerates while the portion in connection with the ganglia and the sensory fibres is unchanged. (3) Section of nerve trunk i. e. outside the junction of the nerve roots. All the fibres in the separated portion of the trunk degenerate while the roots and the portion of the trunk in connection with them are unchanged. The excision of the ganglia causes the whole of the posterior root and sensory fibres in the trunk to degenerate. Some few fibres found in the posterior root seem to run into the anterior root as when the posterior root is cut outside this ganglia scattered degenerated fibres are found in the anterior root. These

are called the fibres of recurrent sensibility.

Irritability of Nervous Tissues:—The living corpuscles, the nervous centers and in the nerve fibres, which are simply altered corpuscles, possess irritability i. e., they respond to stimulation. But in neither of these, i. e. the nerve centers and the nerve fibres does the response take such a decided form as does that manifested by muscular corpuscles. A demonstration of the nervous irritability may be easily made. If the body of a decapitated frog is not interfered with in any way it will remain perfectly still, while the muscular and other tissues gradually lose their irritability and ultimately decompose. But if shortly after decapitation the spinal cord containing the nerve centers, be stimulated or irritated in any other way, certain muscles will contract as is manifested by the movement of the limbs, this irritability of the nerve centers has in some way or other stimulated the muscles of the frog. Again instead of applying the stimulus of the spinal cord, if the surface of the body be irritated, e. g. by pinching or applying a drop of acid, then the muscular contraction and movement will also result. The stimulus applied to the skin has in some way affected the muscles. But before applying the stimulus to the surface, if the nerves passing from the integument to the spinal cord be destroyed, or if the centers in the spinal cord be destroyed or if the nerves from the spinal cord to the muscles be divided, the movements do not take place, evidently then when the irritant was applied to the cord it stimulated the nerve centers and they responded by stimulating some nerve fibers passing between themselves and the muscles, called efferent or motor fibers. The change produced in this way in the nerve fibres, called a nervous impulse travels along the nerves, reaches and stimulates the muscles which respond as usual by contracting. In the case where the irritant was applied to the integument it is clear that it must have produced some change, i. e. it stimulated the nerves passing from the surface of the body to the center in the spinal cord called the afferent or sensory fibres. The impressions so produced in the afferent nerves must have traveled along them, reached and stimulated a center or centers in the cord and as a result of this, one or more impressions were aroused in an efferent nerve or nerves, which traveling along these nerves stimulated various muscles to activity. From these facts as stated it is evident that nerve centers may be stimulated, (1) directly or (2) indirectly through afferent nerve fibers, and the nerve fibers may be stimulated (1) either directly or (2) indirectly as a result of changes occurring in the corpuscles of nerve centers. Of the nature of the changes themselves which take place in nerve centers as a result of stimulation we are ignorant. Nerve centers may be divided into two classes, (1) centers which receive impressions and (2) centers which originate impressions, the same center however may at different times both receive and originate such impressions. Some centers when they receive an impression have the power in some mysterious way of communicating the fact and their sensation (or the consciousness of an impression) results, other centers have no such power and therefore when they receive an impression there is no conscious-

ness of the impression, no communication of the fact to the mind and therefore no sensation. For example, in the instance of the irritation of the skin of the decapitated frog, the nerve center in the spinal cord received an impression, but obviously did not communicate the fact to the sensorium and consequently no sensations were caused. But as the result of stimulating the center by an affernt impression, another impression was sent out by the center along an efferent nerve and the muscles are thus stimulated to contract. There is in such a case no sensation nor any action of the will. The movement is involuntary, the action is spoken of as a reflex one. In regard to the center in which impressions originate, some of these are stimulated by the will—voluntary centers— while others are without any voluntary influence. The term, automatic, although applicable to the center resulting from the activity of both of these kinds of centers, is generally restricted to those on which the will has an influence. The term voluntary is restricted to those which the will irritates. Nerve centers may be classified as follows: (1) Those which receive impressions, of these there are two kinds (a) those which receive impressions and communicate with the sensorium, consciousness of an impression or true sensation results. These are the time sensory centers (b) those which receive impressions, which cause them to originate other impressions. No communication with the sensorium follows and no sensation results. These are reflex centers. (1) Those which originate impressions, either (a) under the influence of the will, called voluntary centers or (b) without the influence of the will, called automatic centers. Nerve centers are sometimes classified according to the actions in which they are concerned, e. g. phychical centers, inhibitory centers etc.

Nerve Terminals:—These terminators are the agents of nervous impulses the fibers being the media of communication with one another, one set of these terminators is found on the body surface and is capable of receiving influences from the outside. These receivers of external stimuli are very varied in character so as to be capable of receiving the various kinds of extrinsic stimuli. They may be either distributed over the whole external surface so as to be brought into contact with external stimulation or they may be localized and specialized so as to receive sonorous, luminous odorous, gustatory influences.

In the latter case the terminators are localized into one part forming the complex organs of sense. Another kind of terminators is found embedded in the deeper structure acting as local distributors of impulses e. g. the skeletal nerve plates, ganglionic network in the intestinal walls, in many cases the connection between the tissues and the nerves is not yet understood. Another class of terminators is called ganglion cells in which the cells are collected together to form a group, these constituting the central terminators found in the cerebro spinal axis or in the ganglia centers. These nerve cells have all processes branching out from the centers as a means of communication with the nerve fibers. In this way the connection from the terminators is complete throughout the entire nervous systen. In the nerve centers we find a distribution of action corresponding with the division of labor. The in-

itial action is performed by a very complex set of organs especially adapted to receive impulses or sensations from the outside. This excitation is then transmitted by means of nerve fibres, to the central nervous cells which seem to perform the function of classifying, dividing and redistributing these impulses as well as in certain cases restraining impulses so that the higher nerve cells may be free to utilize these impulses. Associated with these higher nerve cells we find these centers which can imitate impulse within themselves without external stimulation thus possessing the capacity of imitating energies within themselves.

The functions of these centers of action may be classified as follows: (1) The reflex action. These nerve centers possess the capacity of reflecting impulses received from an afferent nerve, sending the impulse by an efferent nerve to some of the active tissues, (2) acceleration. Some centers have the power of increasing to response to a given stimulation—this augmenting power depending upon the central nervous cells rather than upon any local causes. (3) Co-ordination. Reflex actions require the co-operation of several centers e. g., there are receiving cells, distributing cells and directing cells —all of these co-operating in the nervous impulse. (4) Inhibition. Certain nerve cells restrain other cells or tissues, either restraining the receptive power or diminishing the impulse distributed and sent on. (5) Automatic actions Certain nerve cells have the power of originating impulses without any external exciting stimulation. The best example of automatic action is found in the center controlling the respiratoy movements. All or at least almost all these automatic actions are connected in some way with reflex actions. In these nerve centers we find the mental activity, the functions pertaining and discharged by these centers forming the basis of the mental acts which we classify under perception, conception, thought, memory and volition. The psychic question is one of correct distribution in the care of these functions for the adequate development of the mental activities. The operations of the mind are related in some way to these actions which result from a long series of extrinsic and intrinsic stimulations, modified, limited, and enlarged by those internal influences which are brought to bear upon the nerve cells and centers, depending upon activity, association, hereditary transmission and contact with the external world of sense.

Irritability of Nerve Fibres:—It has been shown that nerve fibres may be aroused to activity, either directly or as a result of changes occurring in nerve centers. They themselves possess no power of originating impressions so that their function is purely one of transmition or communication. Those which convey impressions in words to nerve centers are termed afferent or sensory. Those along which impressions travel outwards from nerve centers are termed efferent or motor. That some change is produced in a nerve fibre as a result of stimulation and that this change passes along the fibre is evident from some of the experiments already described. It may also be demonstrated by stimulating a motor nerve at some distance from the muscle when the muscle will be seen to contract. The nerve may be said to respond to a stimulus by becoming excited, and this state of excitement is con-

ducted along the fibre. Hence the nerve fibres are said to possess excitability and conductivity. The essential part of the nerve fibre, that is the part in which excitability resides and along which the impression travels is the axis cylinder. Its irritability may be aroused by various forms of stimulation, e. g. mechanical, chemical, electrical and thermal. It is not known what is the exact nature of the changes set up in a nerve fibre as the result of stimulation, but the comparatively slow rate at which the change travels along the fibres, viz. 100 to 120 feet per second, eight or nine times more rapid than the wave of contraction passses along a muscle, seems sufficient to show that it is not of the same nature as an electric current. Whatever is its nature the actual change in the nerve fibre appears to be identical whether the impression is traveling inwards along an afferent or outwards along an efferent nerve. The difference in the ultimate effect produced depends not on any difference in the nerve fibre or the nerve currents, but in the varying nature of the structure in which the nerves terminate, e. g. sensory centers, muscles, etc.

Indeed it may be that when a nerve is stimulated in some part of its course an impression travels from the stimulated part in both directions. Various circumstances influence the degree of excitability of the nerve, e. g. the state of its nutrition; the alternate period of rest and activity; various chemical agents; temperature, the passage of a continual current of electricity etc. etc. It is known that the further a motor nerve is irritated from the muscle the greater is the excitability of the one end and the contraction of the other. This is Pfluger's law of contraction. If the sciatic nerve of a frog connected with the isolated limb is stretched over two wires passing from the positive and negative poles of a combination of grove's elements with a distance of one and one-half inches between the wires—if a key be interposed in the circuit a current will thus pass along one and one-half inches of nerve when the key is closed and be cut off when the key is open. By having also communicator or receiver in the circuit we can send the current up or down the nerve at pleasure. Arrangements can also be maee for irritating the nerve by another pair of wires coming from an induction machine either near the negative or positive pole of the current coming from the grove element. It will be found that near the negative pole excitability of the nerve is increased while near the positive pole it is diminished, i. e. the nerve near the negative pole is more excitable than in the normal state, whereas, near the positive pole it is less excitable, indicating that one of the physiological properties of a nerve fibre has been changed by the action of a continuous current. Other theories have been advanced to explain the phenomena. The one designated the avalanche theory of Pfluger supposes that the nerve current gathers force as it travels along the fibre. This seems to be incorrect. The other theory seems more nearly correct which suggests that the nearer the nerve approaches the center with which it is connected the greater is the degree of irritability with which it is endowed.

The effects of passing a continuous current of electricity through a nerve: An electric current applied to a nerve produces stimulation only at the moment

of entering and in leaving it. During the passage of the steady and continuous current the nerve is said to be in the electro-tonic state. While in this state some of its properties differ from the normal. The portion of the nerve around the positive pole or anode is termed the anelectrotonic; the portion around the negative pole or kathode being called the katelectrotonic part. In the former case electrical tension is increased, while the excitability and conductivity are diminished; in the latter case the changes are just the reverse. Between the two parts when the nerve is in the electrotonic state there is a nutral point or a point of indifference in which the properties of the nerve seem to be unchanged and the position of this point seems to depend on the strength of the current. When the current is strong the point is near the negative pole, i. e. the nerve near the positive pole is an electrotonic, the excitability being decreased; when the current is weak, the point is near the positive pole, i. e., the nerve near the negative pole is katelectrotonic, the excitability being increased; if the current is medium, the point of indifference lies midway between the poles, and the excitability is therefore normal.

Physical Properties of Nervous Tissues:—Nervous tissue is soft and diffluent. Any slight degree of firmness, cohesion or consistency in the nerve center is due to the delicate neuroglia, a kind of cement formed of a substance allied to keratin, a whitish homogeneous substance of epithelial origin, which supports the nerve corpuscles binding together individual nerve fibres and ganglion cells. In nerve fibres the contents of the primaative sheath exist during life in a semi-fluid condition and the toughness and strengh of the nerve trunk is dependant on the cornu tissue of granular matter or spongy horn substance binding together the nerve fibres. The elasticity of nerves is not perfect. The white matter consisting of nerve fibres absorbs fluids containing saline substances in different preparations, e. g. sodium chloride is not absorbed at all, sulphate of soda only very slightly while the salts of potassium are absorbed very freely.

Chemical Properties of Neve Fibres:—The chemistry of nervous tissue is but little understood as yet. The corpuscles and nerve centers are albuminous in their natures In the nerve fibre the axis cylinder is alkaline albuminoid while the white substance of Schwann yield cholesterin, fatty substances, neuro-keratin. Hence in gray matter, i. e. nerve corpuscles with nerve fibres consisting of the axis cylinder only, the proportion of albuminous matter is much greater than in the white matter, i. e. the axis cylinder with the white substance of Schwann. In this latter fatty substances preponderate. The primitive sheath seems to be of a similar nature to elastic substance. The chemical changes which take place in nerves during the passage of a nerve current are not known. It is said that a small proportion of heat has been detected during activity. The specific gravity of gray matter varies from 1029 to 1038, and that of white matter 1038 to 1043 indicating that the white matter contains less water, the amount varying in different parts of the brain and nervous system. Bernhardt found in the sympathetic 64 p. c., in the cervical spinal 73 per cent in the medulla oblongata 74 per cent, and in the cortex cerebri 86 per cent.

The albuminous matter in the nerve cells and axis cylinder is not myosin, as it is not soluble in a 10 per cent. solution of sodium chloride. The nerve fibres have been found by a process of artificial digestion to contain neuro-keratin, a substance found in a layer immediately around the axis cylinder, chiefly in the Schwann sheath. Nerve cells and nerve fibres also manifest the presence of phosphorous. the fresh gray matter having yielded 49 per cent and the white matter 89 per cent of phosphorous. Gray matter in reaction is slightly acid, after death the activity becoming more marked. White sustance on the other hand is neutral and at or after death becomes alkaline. The substances so far found in connection with the nervous tissue are complicated in their chemical characteristics. We await researches for more definite results.

Reproduction of Nerve Fibers:—If the cut ends of divided nerve trunk were united new fibres would be formed in the degenerated portion. This seems to be due mainly to the elongation and division of the axis cylinder of the central part of the nerve, but some difference of opinion exists as to the exact nature of the part played by the axis cylinder in the degenerate portion and also by the proliferating neuclei found on the deep surface of the primitive sheath.

Reflex Action:—A reflex action is one that takes place independently of consciousness and without any voluntary effort. the primary excitation being applied to an afferent (sensory) nerve. In every reflex action there are concerned, (1) an afferent nerve, (2) a nerve center or a group of connected centers and (3)an efferent nerve or nerves passing to some peripheral structure, e. g. a muscle, a gland, a blood vessel, etc. The stimulation of the skin of the decapitated frog with its resulting movements has already been referred to as an example of reflex action. The afferent impulses, we saw, reached the nerve center and the efferent nerve impulses were given out from the nerve center. But the nerve center must not be regarded as transmitting merely the afferent into an efferent impulse, for the efferent may bear no certain proportion to the absolute intensity of the afferent impulses, e. g. the smallest particle of any foreign substance passing into the larynx may set up the most violent coughing of a reflex nature, the muscular contractions and therefore the efferent nervous impulses being altogether out of proportion to the intensity of the stimulus and consequently to the afferent impulses. The reflex center is not to be regarded merely as a shunting station, but rather as a store house of latent energy which is set free and made manifest when an afferent impression reaches the center. A reflex action may be limited to a single muscle or a group of muscles or it may effect many groups of muscles (diffusion of the reflex action) or muscle glands, blood vessels, etc. Further the stimulus that arouses a reflex center may at the same time stimulate a center connected with consciousness, but in this case the movements following the activity of the reflex centre are quite independent of the activity of the true sensory centres e. g. mustard in the mouth. In reflex action we have (1) the primary excitation. This may take place in nerves of general sensibility or the nerves of the special senses. Some nerves more easily excite reflex actions

than others e. g. contraction of the pupil under the influence of the light falling on the retina. The afferent nerve is the optic, the centre is the corpora quadrigemina, the efferent the third cranial nerve. (2) A reflex action may follow the excitation of the sensory nerves either at its beginning or at some point in its course. In the latter case the action is less active. (3) The gray substance containing the nerve cells forms the chief part of the reflex centres and we find groups of such reflex centres connected by immediate fibres. The power of excitation ceases if these nerve centres are isolated from the psychic centres which direct voluntary activity e. g. after decapitation reflex actions take place with more intensity than in the living animal. These reflex actions may be inhibited therefore from higher centres and this is termed inhibitation of reflex action. (4) Reflex action may take place in a single muscle or in a group of muscles. The muscles may be grouped according to the stimulation and the degree of excitement of the reflex centre. Pfluger has shown that in the case the decapitated form, excitation of the skin of one hind leg results in transmission from the centre of impulses to the muscles on the foot on the same side; by increasing the excitation, it is transmitted to a centre on the other side and the muscles of both hind legs contract; by a still further increase of excitation the stimulation is transmitted to the higher centers and contraction of the front limbs results; if the stimulation is still increased, the highest reflex centres may be reached and the result is a general contraction of all the muscles. (5) Sensory stimulation may result by a reflex process in motion, secretion and consciousness e. g. mustard in the mouth may produce involuntary movements, salivary secretions, and a conscious sensation. (6) The use of certain substance increases reflex action e. g. strychnine, whereas certain substances diminish excitability e. g. potassium bromide, atrophine, chloral hydrate. (7) In order to produce reflex action in certain cases a number of excitations are necessary. If the individual stimulus is weak no reflex action follows. If these individual stimuli are applied rapidly the sensation of stimuli affects the centre. In certain cases also reflex actions is produced as a result of the action of a series of centres in which the cerebrum centres control the deeper brain ganglia and these deeper brain ganglia control certain centers in the spinal cord. This is called the superposition of reflex actions. (8) The time occupied by these reflex actions can be approximated by measuring the time between stimulation and movement and subtraction from this total time the time necessary for the stimuli to pass along the nerves and the latest period of contraction. The amount of time left will represent the period of reflex action. It is found to be .0555 to .0470 of a second. It may be shortened by strengthening or by the chemical action of strychnine.

Inhibitory Action—In the case of the decapitated frog it was seen that the nerve centers in the spinal cord were aroused to activity and nervous impressions reaching them along afferent fibres. The nerve centers previous to the reception of these impressions were in a state of repose, for until they were thus stimulated there were no movements of the limbs observable. But it may happen that afferent impressions may

reach centers which are in a state of activity, efferent impressions passing from these centers at intervals and producing more or less rythmical movements as the result of the alternate contraction and relaxation of muscular fibres stimulated by these impressions. When this occurs the activity of these active nerve centers may be modified by the impressions which reach them. In the first place that activity may be increased and the nerve fibres which convey the impressions that have this result are spoken of as accelerating fibres. On the other hand the activity of the active nerve center may be diminished or suspended altogether, such an effect being an inhibitory action and the nerve fibres along which the impressions that thus lessen the activity of a working nerve center pass are called inhibitory fibres. These impressions are in certain cases originated by nerve centers, that is, one nerve center may originate an impression that restrains the activity of another nerve center or centers. Hence the originating center here may be called an inhibitory center. An example of this inhibitory action occurs in connection with respiration. This process is due to the alternate contraction and relaxation of certain muscles under the influence of the rythmic nervous impressions eminating from a center situated in the medulla. Certain nerve fibres in the superior branch of the vagus nerve are associated with this center and on stimulation of these the activity of the center is diminished or suspended and the respiratory movements slowed or altogether stopped. The impression conveyed by the nerve fibres has inhibited the activity of the respiratory centers. Again there are certain nerve fibres the stimulation of which produces contraction (vaso-constrictor fibres) of the blood vessels with which they are connected, for stimulation of other nerves produces dilation of the blood vessels (vaso-dilator fibres). These latter are supposed to produce such a result by inhibitory action. Other examples are found in the slowing of the heart's action when the vagus is stimulated. Nerve fibres may be most conveniently classified as follows:

I. Centrifugal, efferent or motor nerves, carrying influence outwards from some nerve center. Of these there are five subdivisions:

1. Motor, sometimes called efferent, passing to muscles, causing contraction.

2. Secretory, passing to the cells of glands, influencing secretion, some say causing seeretion, at least a special kind of secretion.

3. Vaso-motor, passing to the walls of the blood vessels, influencing their calibre; these are either vaso-constrictor, causing contraction, or vaso-dilator (vaso-inhibitor) causing dilation.

4. Proper inhibitory nerves, influencing other centers of nerve activity so as to neutralize, or at least moderate their action.

5. Electrical, so affecting a particular organ as to produce electric discharges, as in the case of the electric fish.

II. Centripetal, efferent or sensory nerves, carrying Influence inwards to the nerve center. These are;

1. sensory. producing more or less acute sensations, either general and vague, carrying to nerve centers in the brain, impulses which produce sensations that are hardly perceptible to consciousness and not of a permanent character, e.

g. impulses from the lungs, heart, stomach or special and distinct carrying impulses to the brain nerve centers, which give rise to sensation associated with the special senses, limited to the social organs of sense.

2, Afferent or reflex, passing to centers and conveying the stimulations which do not necersarily cause sensation and which may or may not be followed by motions, secretions, changes in the calibre of the vessels.

3, Inhibitory, passing to centers whose activity they restrain.

4. Connecting, nerve fibres which pass from nerve centers to terminal or end organs and also nerve fibres connecting nerve cells-in the large nerve centers.

The peripheal extremities of the nerve fibres terminate, at least in many cases, in some special structures which are spoken of collectively as end organs, e. g. end plates in muscles, the rods and cones in the retina, etc. It is probable that in normal conditions it is always through these that the nerve acts or is acted upon. More over they are not to be regarded as structures that merely transmit a stimulus to or from a nerve, but rather as storehouses of various forms of energy which is liberated on stimulation and which in the case of afferent nerves causes the stimulation of the nerve, and in the case of efferent nerves the contraction of muscles. Thus light will not directly stimulate the fibres of the optic nerve. It will only act on that nerve through the rods and cones of the retina in which it produces certain changes. It is these changes that stimulate the nerve fibres.

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# Respiration.

Respiration is essentially the interchange between the gases of the organism and the gases of the medium in which the organism lives.

Oxygen is essential to the life of every tissue whereas carbonic acid, one of the products of organic life, is destruction of life. The simplest organisms, such as the amoeba, when deprived of oxygen or put into a medium overcharged with carbonic acid becomes exposed to death, so that for the sustenance of these simplified forms of life, fresh oxygen must be brought in and the carbonic acid must be removed in order to preserve life. This interchange of gases is constantly taking place in all forms of animal life. In the lower organisms in which the structure is simple and the life less complicated, no complex organisms are either directly plunged in the fluid upon which they live or have certain passages throughout their system in which the fluid passes to all parts of the organism. In the higher organisms in which the fluid circulates through the system arrangements are necessary for the interchange of gases between the fluid and the surrounding substance of the bodily organs, e. g. the tracheae found distributed over the bodies of insects, the gills of fishes. In still higer organic life we find differentiated organs in the form of sacs with tubes communicating with the

surrounding medium, the blood vessels lining the walls of this medium furnishing a means of interchange between the internal and external gases.

This sac in higher animals passes into the complicated honeycomed lungs, whose structure is such that cells with minute capillaries present a large surface in which this gaseous interchange is constantly taking place In these highest forms of animal life there is a definite mechanism involving muscular movements and nervous actions for the purpose of in troducing into, distributing and expelling the air from the organs of respiration. Its object is two-fold:

1. To take a fresh supply of oxygen, such as is found necessary for the process of oxidation in the body.

2 To expel the carbon dioxide formed within the body. In complex organisms, such as the human subject, the phenomena of respiration may be divided into two parts:

1. There is the interchange of gases which occurs between the blood and the tissues, sometimes spoken of as internal respiration.

2. In order that the process may go on successfully there must be an interchange between the gases in the blood and the gases of the surrounding atmosphere, this external air being introduced into the air cells of the respiratory organs. This latter interchange is termed external respiration. In man this is carried on chiefiy but not entirely in connection with the lungs. Hence this is called pulmonary respiration. There is a subsidiary respiration carried on in connection with the skin, called cutaneous respiration, as well as intestinal respiration in the intestines and possibly some interchange in connection with some other organs. Both of these interchanges are in the main physical processes being due to the mutual diffusion of the gases and depending but slightly upon the epithelial cells that cover the surfaces through which the passage of the gasses takes place. The respiratory apperatus therefore in man consists:

1. Of the lungs with a large number of air vessels connected with a dense plexus of blood vessels.

2. The air passages leading to the lungs and communicating with them, including the nose, pharynx, larynx, trachea and bronchi.

3. The thorax and the muscular mechanisms connected with it by which the lungs are filled and emptied,

4. The nervous mechanism of respiration.

5. The subsidiary function discharged by the skin in respiration.

Respiratory Apparatus.—The larynx is made up of several pieces forming a cartilaginous framework the different parts being movable upon one another by means of muscles. There are three single cartilages, thyroid, cricoid and epiglottis and three pairs of cartliages, arytenoid and the cartiligages of Santorni and Wrisberg. The thyroid consists of two lateral plates which meet one another at an angle anteriorly forming the prominence known as Adam's apple, and bearing between them posteriorly a wide open space. The cricoid cartilage placed between the thyroid and trachea is shaped like a signet ring, the deep part being behind, the seal projecting upwards. On the lateral part of the upper border of this seal there is on each side an oval surface for articulation.

The external surface of the cartilage is smooth in front but at the sides it becomes irregular and furnishes attachment to the crico-thyroid muscle and to the superior constrictors of the pharynx. The epiglottis is a plate of yellow elastic cartilage shaped like a leaf, the narrower lower part being attached to the deep surface of the thyroid cartilage in the middle line, the broad upper part projecting upward at the root of the tongue. In swallowing this part is pushed downwards and backwards so as to be horizontally over the superior aperture of the larnyx. During respiration its direction is vertically upward the free surface curving forward towards the base of the tongue. It is covered with mucous membrane and two folds of epiglottidean ligaments, underneath the mucous membrane being a number of small pits in which are lodged small glands opening on the mucous surface. The mucous membrane of the larnyx is thin and pale and has numerous glands opening on the surface, except at the upper and especially at the upper lateral part and over the true vocal chords where it is sqamous, the epithelium being columnar and ciliated. The mucous membrane is continuous below with that of the trachea; as it ascends it turns inward to pass over the edges of the true vocal chords. Again it passes outwards and then ascends a short distance, on each side forming a fold, each fold, overhanging the true vocal chord and forming the false vocal chords. The true vocal chords are bands of elastic tissue covered with mucous membrane, this mucous membrane being very thin and adhereing closely to the elastic bands. The false vocal chords are simply folds of mucous membrane. The superior aperture of the larynx is triangular in shape, wide in front where it is bounded by the epiglottis and narrow behind where it is limited by the tops of the arytenoid cartilages and the cornicula laryngis. The sides of the superior aperture are formed by the aryteno-epiglottidean folds which slope downwards and backwards from the sides of the epiglottis. The superior aperture is closed during swallowing by the bending backwards over it of the epiglottis on the deep surface of which in the middle line is the cushion of the epiglottis by which the accurate closure of the epiglottis is secured. The trachea or windpipe is a a cartilaginous and membranous tube. It passes downward in the middle line from the cricoid cartilage acout 4 1-2 inches and then bifurcates to form the bronchi, one for each lung, the division taking place about the level of the upper border of the 4th dorsal vertebra. Its diameter is from 3-4 of an inch to one inch. In front and at the sides the trachea is firm and resistant due to the presence of transverse bands of cartilage. These form imperfect rings, the deficiency being behind where there is found a narrow compressible membranous part. These rings are from 16 to 20 in number and sometimes preseut a bifurcated appearance. They are joined together by a coat which contains some elastic fibres. On the deep surface of the fibrous coat there are found fibers of unstriped muscle arranged transversely. Within the fibrous coat is the submucous coat in which are found small mucous glands. The Bronchi correspond in structure with the trachea. The right bronchus is wider, shorter and more nearly horizontal than the left one. The bronchi entering the

lungs branch again and again forming finer and finer bronchial tubes each of which ends in a dilatation called infundibula, changes take place in the structure of the air tubes as by repeated branching they become narrower till they end in the infundibulum. The fibrous coat becomes thinner and thinner and very distinct bundles of longitudinal yellow elastic fibers are found. The cartilage is found in small plates so arranged that together they completely surround the tube making it quite cylindrical. The plates of cartilage gradually become smaller and in the capillary bronchial tubes have entirely disappeared. The transverse muscular fibers form a layer all around the tube inside the cartilage, in the very finest tubes the muscle has disappeared. The mucous membrane gradually becomes thinner but retains its columnar cilitated epithelium until just before the tube expands into the infundibulum where patches of squamous epithelium are found. Each of the finest bronchinles presents near its termination little resesses leading off from it called air cells. The tube ends in an inversely funnel shaped expansion known as the infundibulum consisting of a portion of expanded tube into which open a number of air cells. These air cells have a wall of elastic tissue, lined by an epithelium of large thin flat cells with smaller flat cells between them. Beneath the epithelium is an extremely dense network of capillaries. The septa between the adjacent air cells are composed of a double layer of epithelium between which is a single layer of capillaries, the blood in these capillaries being exposed to the action of the air on each side.

The lungs are made up of bronchial tubes ending in the infundibula held together with a connective tissue, which contains some pigmented corpuscles and in which run blood vessels, nerves and lymphatics. The infundibula or ultimate lobes are there joined together into larger lobules, the outlines of which can be distinguished on the surface and which may be dissected from one another in the foetal lung. The lung substance proper is divided by connective tissue into small lobules. The connective tissue between the lobules is continuous with a thin layer of connective tissue containing numbers of elastic fibres immediately below the pulmonary pleura. The interlobular connective tissue is highly developed in children. The right lung is the larger, broader and shorter of the two. The blood for the nourishment of the lung substance reaches the lung by the bronchial artery and is returned by the bronchial vein. Each lung is completely invested with a serous membrane, the pleura, the viceral layer of which is adherent to the surface of the lung, while the parietal layer is reflected from what is called the root of the lung where the bronchus and blood vessels enter the walls of the chest, the outer surface of pericardium and the upper surface of the diaphragm. Beneath the pleura there is a lymphatic pelxus which communicates with the deeper plexus in the connective tissue binding together the small lobules. From these lymphatics arise vessels which run along with the bronchi and convey the lung lymph to the bronchial glands.

THE MECHANISM OF RESPIRATION:—The movements in respiration consist of certain rythemic changes in the thorax partly caused by contraction and relaxation of the muscles and partly dependent

upon the elastic character of the organs. The thorax is a closed box containing two elastic bags, the lungs, which communicate with the external atmosphere by means of a common tube, the trachea. As the thorax is a vacuum the pressure of the air inside the lungs stretches and expands these elastic structures, so that they are always pressed against the thoracic walls. An increase in the volume of the thoracic cavity is followed by an expansion and a decrease in the volume of the thoracic cavity by a contrac- of the lungs The visceral and parietal layers of the pleura are thus kept in contact with one another. The fact that the lungs are always stretched is shown by what takes place when air e. g. from an external wound is admitted into the cavity of the thorax (pleura). Under such circumstances the atmospheric pressure exerts its influence upon the external surfaces (the plural) and the internal surfaces (the bronchial tubes and air cells) of the lungs. This elastic bag then collapses leaving the pleural sac full of air, called pneumothorax. By the activity of the respiratory muscles the chest capacity is extended on all sides. This results in a greater atmospheric pressure than that on the external surface of the lungs and thus there is forced into the air passages of the lungs a certain quantity of air until the pressure becomes equilibrated. Inspiration is primarily a muscular action. In expiration on the relaxation of the muscles the lungs and the thoracic walls on account of their elasticity, assisted by muscular contraction, causes the chest to recoil into its proper position. Thus the internal pressure of the lungs become greater than the external pressure and the air is forced out through the trachea. Expiration is not a purely muscular act, but a result of the elastic structure of the organs. Inspiration and expiration act together to form respiration. If the thoracic wall be punctured upon one side then the one lung gives up its activity resulting in hardness of breathing; if the other side is also punctured both lungs give up and asphyxia follows, because there is no lung expansion, the internal and external pressure being equalized. The normal condition of the lungs is that of partial distention. Respiration never reaches its maximum of expansion. Complemental air may be forced into the lungs by means of a labored inspiration due to the expansion of the chest cavity under strong muscular action. Likewise respiration never reaches its maximum of contraction for the supplemental air cannot be forced out by muscular contraction. Even in this latter case where a considerable volume of air is expelled there is always left the residual air. There is constantly an elastic conflict between the pulmonary and parietal pleura, but this in normal condition never results in the destruction of either, because the air cannot penetrate the pleural cavity. In the case of puncture of the chest wall, the air penetrates the pleural cavity the result being the separation of the pulmonary and parietal pleurae thus forcing out the air through the trachea.

Even in such a condition there remains a residuary portion of air in the lungs, the infudibula where walls are soft retaining the air passed from the minute bronchioles. In the foetal life there is no air in the lungs, being in the conditions of atelestasis, the air cells not being expanded. Those air cell walls lined with

nucleated cells and well rounded cell substance are adhesive, no cavity as yet having been formed. The small bronchial walls are likewise adhering while the large bronchial tubes and the trachea have a distinct tubular cavity but it is filled with fluid. At birth the first volume of air is admitted to the trachea and larger bronchi passing them with considerable force into the bronchioles and the air cells of the lungs, separating the walls and filling up the distended cavities. A large quantity of the first inspired air in the new born child remains within the air cells and passages; only later when these become fully distended does the expiratiory process become complete, the complete respiration being gradually established. Though the lungs are very elastic, they can not expel all the air because the air pressure on their internal surface is greater than the elasticity of the lungs and the chest walls. This pressnre can be measured. In the dead subject the manometer can be connected with the trachea. When collapse takes place the mercury will rise. Donders found the presssure under such circumstances to be 2 to 3 mm. In life the pressure is estimated about 7.5 mm. that is about .01 of the atmospheric pressure. In the case of forcible distention of the chest the pressure was found to be 1-25 of the pressure of the atmosphere or, 30 mm. In the living subject, the expelling force is greater because the muscular fibres of the bronchi aid the elasticity of the lungs. This however is small compared with the pressure of lung elasticity. By introducing the manometer into the windpipe of an animal through a lateral opening there has been found a negative pressure during inspiration indicating the fall of mercury and a positive pressure during expiration indicated by the fall of the mercury. The same negative and positive pressure may be found by introducing the manometer into the trachea at the mouth or through a nostril, the amount of pressure being determined by the strength of the inspiration or expiration. The spirometer has been made use of to measure the highest amount of air that can be forced out by the strongest expiration, the amount varying from 2000 to 4000 cc.

INPSIRATION :—In inspiration the cavity of the thorax is enlarged, (1) vertically. The vertical diameter is increased by the contraction and discent of the diaphragm, the anterior abdominal wall protruding. In man the diaphragm is a partition wall separating the thorax from the abdomen, ellipitical in shape, the convex part being directed towards the thorax. On the contraction of the muscular fibres the middle part descends and the diaphragm becomes flattened. From the sides it descends further than from the central part. The pressure downwaad is trasmitted to the abdomen, especially to anterior abdominal wall, producing a bulging outwards.

2. The cavity of the thorax is enlarged antero-posteriorly and transversely by the elevation and rotation on the antero-posterior axis of the ribs and the carrying forward of the sternum. These movements are the result of muscular contractions. As the thorax enlarges the lungs necessarily enlarge, otherwise there would be left a vacuum between the pulmonary and parietal pleura. The increased expansion of the lungs mean rarefaction of the gases they contain. that is, the pressure of the gas inside the

lungs falls below the pressure of the external atmosphere which therefore rushes down the trachea until equilibrium is restored. These two main causes of enlargement is normal inspiration, the descent of the diaphragm and the elevation of the ribs, gives respectfully the diaphramatic breathing, characteristic of the male, and the costal characteristic of the female. The lowering of the diaphragm is mainly due to muscular contraction. The elevation of the ribs is more complicated. The ribs are radii moving on the vertebral arthrosis as a center. At rest it is obliquely directed from the spine towards the sternum. When it moves freely its sternal attachments move forward more horizontally further away from the spinal centers. As all the ribs have a slanting direction downwards, on being raised they push the sternum forward, more or less, according to their length. The frontal surface of the chest is thus pushed forward and upwards as the ribs are raised. The rib arch increases from the first to the seventh ribs, the elevation of the lower ribs thus increasing the antero-posterior diameter and also the transverse, providing for the considerable enlargement of the chest. The elevation of the ribs is accomplished by muscles. The muscles concerned in ordinary inspiration are the diaphragm, the external intercostals, some say also the internal intercostals, the levatores costarum and to some extent the scaleni. The external intercostals are the most important. The act of elevation over the entire chest is greatly aided by the fact that the second rib is more movable than the first, thus furnishing a firmer base upon which the muscular action rests. Each one in turn from the first onward supporting the next. The scaleni acting as an additional base of support for the first two.

In deep inspiration the antero-mastoid raises and supports the first two ribs by pulling up the sternum and fixing the clavicle so as to form a solid foundation for the muscular action of the chest. The serratus posticus superior also raises the upper ribs, the serratus posticus inferior, quadratus lumborum and other muscles depressing and fixing the lower ribs afford a firm basis for contraction of the diaphragm and thus assist deep inspiration. The intercostals accord to some aid in inspiration; according to others the parts of the intercostals between the sternal cartilages act as inspirators while those parts between the ribs act as expirators. According to others the intercostals take no part in inspiration, simply acting as strengthening the muscles to render the intercostal spaces and the whole chest cavity firm.

Forced Inspiration—Other muscles are brought into play in forced inspiration. The scaleni give firm support to the first two ribs. The seratus posticus superior, gives fixity to the third, fourth and fifth ribs and by contraction raises these ribs. The false ribs become lowered and fixed, adding support to the diaphragm so that it vertically enlarges the chest. In artificial respiration and in forced respiration with fixation of the upper limbs the pectoralis minor, the seratus magnus and the ilio-costalis aid in respiration elevating the ribs and thus increasing the size of the thoracic cavity. In fact all the muscles which can either raise the ribs or aid in fixing the other muscles are utilized in forced respiration.

Expiration:—In normal expiration

the walls of the chest and of the lungs recoil. In inspiration the lung tissue is stretched which continues so long as the muscle contraction lasts. As soon as the inspiratory muscles relax the elasticity of the lungs comes into action and drives out a quantity of air, by the descent of the diaphragm and the springing back of the ribs to their original position the cavity of the thorax is diminished. The lungs therefore occupy a less space than before. This means that their contained gases must occupy a smaller space than before, hence the pressure inside the lungs becomes greater than the pressure of the external atmosphere. The gas therefore rushes out of the lungs through the trachea and a state of equilibrium is regained, Inspiration as we have said before is the result of muscular action, whereas expiration is a passive process at least ordinary expiration is the result in the main of the elastic recoil The elastic cartilages and the ribs as soon as the muscles of inspiration relax, or let go their hold upon the chest, spring back to their original form and size. Ordinary expiration is not the result of muscular contraction Some hold that the intercostal muscles, especially the internal, act as expiratory muscles by depressing the ribs. After normal expiration the lungs are in a condition of elastic tension. When the muscles of inspiration cease to act, this tension comes into operation. The borders of the costal cartilages which are twisted upward and outward during inspiration become untwisted. The intercostal spaces which were stretched during inspiration react. The diaphragm relaxes, pressing back the abdominal walls into place and pushing the diaphragm up into the resting position. Added to this is the weight of the chest wall which tends to return the chest into its former condition. It is generally supposed that internal intercostal muscles contract,- acting the part of depressors of the ribs, but this activity is probably to maintain the tension of the intercostal tissues. When expiration becomes forced certain of the muscles become active. The internal intercostals are probably active at least when the lower portion of the thoracic cavity becomes fixed through the action of the abdominal muscles. This is accomplished by the contraction of the abdominal muscles, pressing the abdominal viscera against the diaphragm which is forced upwards, diminishing the vertical measurement of the thorax. The triangulares sterni lying behind the costal cartilages reach upward and outward from the lower end of the sternum and the deep surface of the ensiform cartilage and the cartilages of the two or three sternal ribs to the lower and deeper surfaces of the cartilages of the second to the sixth ribs. They depress the cartilages during expiration. The seratus posticus inferior arising from the spines of the last two dorsal and upper two lumbar vertebrae pass outward, upward and forward, being inserted into the lower borders of the last four ribs. During expiration they draw the ribs downwards and backwards. The levatores ani come together from the pelvic wall, forming the greater part of the muscular floor of the pelvic cavity and acting as a resistant to the downward pressure of the viscera produced by the strong contraction of the abdominal muscles.

Associated with the movements of the thoracic walls which occur in respiration

other muscular movements also take place. The currents of air that passes in and out of the lungs travel through the nasal cavity, more especially along the inferior nasal meatus. With each inspiration there is a slight expansion of the nostrils due to the contraction of the dilatores naris and to the entrance of air is assisted. By passing through the nasal membranes warmth is given to the air and the mouth is protected from the dryness of the air. During expansion the nasal cartilages spring back to their original size, form and position aided by the compressores naris. The soft plate is moved backward and forward by current, the air ingoing and outgoing; during inspiration the glottis is widely open, which during expiration the arytenoid cartilages approach one another and the cartilages of santorini project inward. Thus simultaneously with the movements of the alae nasi and the thoracic wall there is a widening and a narrowing of the glottis. When breathing becomes labored the mouth is generally opened, the soft palate rises, the larynx descends by the action of the sterno-hyroid and the sterno-thyroid muscles and the glottis is widely open as a result of the action of the crico-arytenoid muscles, the nares are distended by the action of the posterior and anterior dilatores naris and the alae are raised by the levatores labii superiores alaquae nasi.

From what has been said each respiration is seen to consist of (1) a period of inspiration (2) a period of expiration, and (3) a short pause during which there is no movement. In normal breathing the respiratory movements follow each other in regular succession, the expiration being longer than inspiration; in certain circumstances as in excitation of the vagi inspiration becomes two or three times longer than expiration. The pause may be short or long depending largely upon habit. In normal breathing the pause occupied about .25 of a respiratory period, the pause being shortened if the respiration is very active, and increased during sleep, unconsciousness or mental abstraction. The respiratory rate depends upon conditions of age, position, species, temperature, season, activity, digestion etc. etc. In the adult the respirations number about 15 per minute, that is 1 to 4 or 5 of the cardiac pulsations; they are more frequent in the child and are influenced by the position of the body, exercise etc. In aged people the average rate may fall to 10 or 11 per minute. It is said that the size of the body effects the rate, the smaller the body the more frequent being the respiration. In the male and in children inspiration depends chiefly on the descent of the diapraghm and the breathing is abdominal. In the mature female the chest capacity is increased transversely and antero-posteriorly, the breathing being principally thoracic or costal. When the inspirations are very deep the distinction between abdominal and costal breathing disappears, during sleep the difference of breathing in the sexes also disappears, the respiration being entirely thoracic. By the use of the stethoscope in connection with the larynx and trachea two sounds are heard, the one inspiratory and the other expiratory, the laryngeal and tracheal sounds, which are harsh, articulate, the inspiration and expiration being of equal length, with a distinct interval between them. To the right or the left of the manubrium of the sternum similar sounds will be

heard, but less intense called the bronchial sounds. Over the posterior tube of either lung, hear either from the back of the chest are the respiratory murmers. Slow rustling sounds, the expiratory sound being one-third the length of the inspiratory, with no interval between the two. These sounds are produced by the air passing through the trachea, bronchial tubes and lungs. In abnormal conditions the murmur assumes different forms, called rales and souffles. Listening to the sounds during speech produces special forms, pectoriloquy, when the voice sounds through the trachea, bronchophony, sounded through the bronchial tubes, no audible sound being heard in connection with the lungs. By fluid effusion into the plural cavity a peculiar vocal sound is heard over the middle and posterior part of the thorax. of a tremulous, sharp, metallic character called aegophony.

The elastic lungs even after the forced expiration still contain a quantity of air, roughly estimated about 100 cubic inches, called the residual air. At the end of ordinary expiration the emptying of the lungs is not nearly so complete, an additional 100 cubic inches remining in the lungs. This is called the supplemental air, so that after a moderate expiration 200 cubic inches of air remain in the lungs. The amount of air taken in and expelled with each ordinary respiration measures from 25 to 30 cubic inches. This is called the tidal air. By a deep inspiration the lungs may be made to contain an additional 100 cubic inches, which is termed the complemental air. Hence the maximum capacity of the lungs may be roughly estimated at 330 cubic inches, but only 230 cubic inches can be expelled by a forced expiration following a deep inspiration. The term vital capacity is applied to this maximum of air that can be expired after a deep inspiration. As a rule this vital capacity is greater in the male than in the female. increasing up to 35 years of age and diminishing thereafter. It also increases with height and internal capacity of the chest. In a male of about 5 feet in height the vital capacity would be about 2350 c. cm. and in the female about 2000.

Varions instruments have been invented for recording the respiratory movements. Marey's stethograph is the most common. The movements are first communicated by a system of levers to a tambour, passed through a tube to a second tambour which has a level to record on the Rymograph. In the case of the costal movements the stethograph is used, in the case of the diaphragm movements a long instrument is passed through the walls of the abdomen so that the one end rests spoon shaped between the abdomen and liver and the other end upon the recording lever, while the walls of the abdomen act as a fulcrum. It has been found (1) That expiration succeeds inspiration without any pause. (2) That expiration is longer than inspiration, except in abnormal conditions. (3) The inspiratory movement is more abrupt than the expiratory. (4) The expiratory pause normally is very brief. When the respirations become abnormally irregular, the pause is increased. In certain diseased conditions there is a respiratory pause following the inspiration. Some have tried to measure the force of the inspiratory muscles. These muscles require both to overcome the thoracic and the pulmonary elasticity. These resist-

ances may be measured. Pass a tube connected with the short limb of a manometer into the two nostrils and then make an inspiration. The mercury rises in the short limb, representing a negative pressure estimated at from one to three minutes in normal and from 30 to 60 mm. in forced inspiration. In expi-expiration a positive pressure is noticed of two to three mm. in normal and 80 to 120 in forced expiration. By striking an average we find that the inspiratory muscles need to overcome a resistance amounting to 10 mm. in normal and 80 mm. in forced inspiration.

Influence of respiration on the Circulation:—If the brain of a living mammal be exposed, removing the skull, there is noticed a rhythmic pulsation of the cerebral mass, quite different from the pulsation of the brain arteries. These pulsations are simultaneous with respiratory movements, the cerebral mass rising during expiration and sinking during inspiration. If the arteries of the brain be ligatured these pulsations cease, or if the venous blood be allowed to escape from the venous sinues, they arise from the expirations and inspirations that restrain or aid the blood flow from the brain. During inspiration the pressure of the blood in the large veins may be negative, and the puncture of one of these vessels may result fatally from the inspiration of air into the vessels and from thence into the heart. The expansion and contraction of the thorax has a strong influence upon the blood flow through the thoracic cavity, indirectly influencing the whole vascular system. The blood pressure rises shortly after the beginning of inspiration and attains its maximum after a short period following expiration. Afterwards it commences to fall reaching its minimnm after the commencement of the succeeding inspiration. Blood pressure changes result from respiratory movements. The lungs and the heart in air tight cavity, the lungs being distended through inspiratory action, the walls of the air cells having an elastic force depending on the amount of the lung distension. This elastic force exercises a suction influence upon the other organs inside the chest; this negative pressure becoming stronger as the lungs are more fully distended. This negative pressure is called interthoracic pressure which is the cause of sleep, and in rabbits and dogs is said to amount from three to five mm. The presure on the chest organs must have been atmospheric pressure—the negative pressure and the elastic force of the lungs, or about 748 mm. In normal expiration there is a force pressing upon the chest organs equal to the atmospheric pressure together with the positive pressure of expiration, less the inthoracic negative pressure amounting in all to 756 mm. During inspiration, therefore the pressure, on all the thoracic organs except the lungs is less than that upon the vessels outside the chest, thus the aspiratory action of inspiration attracts the blood into the large vessels of the chest. This influence is felt more upon the large vessels than upon the heart, and more upon the veins than upon the arteries on acuount of the soft walls of the veins. Thus the great respiratory influence is felt in the relaxed walls of the large veins. The lungs, heart and large vessels being suspended in the expandible cavity in which they

rest. The lungs communicated with the atmosphere, the heart and vessels with the vessels outside of the chest, are subject to the influences of distension and contraction under respiratory movements. In the case of the lungs themselves, the blood vessels communicate with the external vessels assisting distension of these vessels and promoting the blood flow from the lungs to the left auricle The minute capillaries on the air-cell walls are also subject to greater pressure than the pulmonary veins in inspiration, and thus the flow of blood is stimulated. During expiration the negative pressure is lessened, inthoracic vessels returning from their dilated condition to a normal state. The pulmonary blood vessels are thus left free to relax and they are also interpressed by the air pressure of the lungs and the expiratory influences resulting in the contraction of the pulmonary vessels. More blood is brought into the chest and thence into the heart during inspiration and the blood flow through the lungs is more free, more blood finding its way to the left side of the heart, and thence into the system's circulation. This increased blood supply causes the general blood pressure to rise. The blood flow to the right side of the heart is aided by the action of the diaphragm and abdominal walls transmitted to the abdominal vessels.

Arterial pressure tends to force the blood downward in the body and to restrain the blood flow from the heart, while the flow towards the heart in the veins is increased. The arterial walls are so rigid and thick that this influence does not materially effect arterial blood flow, whereas the venous walls being flaceid and thus tend to facilitate the flow into the heart. The results of this can be seen in case of section of the phremic nerves producing diaphramatic paralysis. The blood pressure curves in this case being very much lessened. This is due to the diminished respiratory actions and to the loss of the pressure communicated from the diaphragm to the veins. The general affect of inspiration, therefore, is to increase the blood pressure, and of expiration to decrease it. The aspiration of the thorax also aids in drawing the blood away from the liver, for when inspiration reduces the pressure on the inferior vena cava, the blood flow through the hepatic veins and the rather slow circulation in the liver becomes accelerated. Some physiologists believe that the rhythmetical stimulation of the vaso constrictor center in the medulla is influenced by respiratory action. These rhythmical stimulations are said to take place simultaneously with the inspiratory action of the respiratory center.

In the case of the human subject it is noticed that during inspiration the heart beat increases, inspiration assisting at least in this way increases the general blood pressure. During expiration the pulse is less rapid than during inspiration. If the pneumogastric nerves be cut, the pulse rate increases, but there ceases to be any difference between it during inspiration and expiration. If, however, the thorax be opened and the pnuemogastrics left uncut there is still an increase in the rate during inspiration. Thus the cardio-inhibaitary center either increases in activity during expiration or less activity during inspiration, the cardio inhibitory centers and the respiratory centers being associated in some way in their action. This sympathy between

these two centers is supposed to depend upon the arterialization of the blood, the greater arterialization of inspiration affecting the cardiac center, lessening its activity during inspiration and producing an increased pulse rate. Deficient arterialization of the blood does affect the vaso-motor system. By placing an animal under the influence of curare so as to remove the conflictions arising from skeletal muscle contractions, if both the vagi are divided so as to check the inhibitory impulses from the center, artifical respiration becomes suspended. Following this there is noticeable a rise in the pressure due to the stimulation of the vaso motor center by venous blood flow producing contraction of the small arteries. especially those of the splanchnic region. When the artificial respiration ceases, the blood pressure rises, at first steadily and then more irregularly. As the blood becomes more venous the vaso-motor centers and the heart becomes weakened. The blood pressure waves produced during normal breathing become more marked as the respiratory movements increase in depth. When the most powerful inspiration is made the lungs are fully expanded and also the heart is greatly distended, the intra-pulmonary and intra-cardiac vessels being also dilated. Although this induces a large flow of blood into the chest cavity, the heart beats may be small, because the negative pressure is so great that the walls of the auricles have to contend against a great pressure in contracting. Only a small quantity of blood is thus forced into the general circulation and the left auricle of the heart through the lungs. If there is a very strong expiration followed by a very powerful inspiration the heart and the vessels become greatly distended. The blood current to the auricle and ventricle increases, the heart and lung vessels become gorged. Only a very small quantiy of blood passes into the systematic circulation and the heart sounds and pulse may disappear. If then a powerful inspiration be made and then a strong expiration, there is high pressure in the lungs. the heart and the large vessels resulting in driving the blood out of the pulmonary circulation into the heart circulation resulting in a rise of blood pressure, the veins outside of the thorax being distended as seen in the veins of the face and neck, the heart being pressed on to such an extent the heart sounds and pulse may disappear.

The respiratory system also bears a relation to other systems of the body. Deficiency in the oxygenation of the blood arouses the muscles in the alimentary canal to activity, having also a material influence upon the perspiration and possibly upon the the secretions. Respiration chiefly in connection with the respiratory center is also influenced by changes effected in the blood by the action of the skeletal muscles, Thus the respiratory system is closely connected with all the bodily organs and may be said to act and re-act upon the system in general. Effort or work performed by the body results in depriving the blood of its oxygen and filling it with carbon dioxide. This creates activity for the respiratory system which in its relation with the other systems provides for that metabolism which provides for the repair of this wasting condition. Respiratory action is aided by cardiac activity, and hence the two go hand in hand in preventing that collapse which is repre-

sented sometimes by want of breath and at other times by heart failure. There are, therefore, two main elements of respiration. (1) Respiration proper and (2) the circulation of the blood to the air. Of course, there is implied in this the normal condition of the blood, its richness is haemoglobin, that is the red corpuscles, for upon this depends the volume of oxygen that is taken from the lungs into the blood. That is evident from the fact that anaemic persons are very easily made breathless, because of the lack of blood supply, and hence the lack of oxygenation. The force of the mechanism of respiration can only deliver to the blood and the tissues the oxygen. The blood itself must take in and utilize this in order that it may be of value to the system. The chief function of the thoracic expansion and contraction is to secure adequate lung ventilation. There are subsidiary functions, however, discharged by these respiratory movements. Some of these are volitional and some are spasmodic. The volume of air, for example, expired from the chest is used to expel certain substances from the upper air passages. Coughing consists of a deep inspiration followed by a partial closure of the glottis, and a sudden expiration, during which the glottis opens forcibly and a volume of air is forced through the upper respiratories, in some cases foreign substances being expelled also. It represents not only an abnormal state of the respiratory, but may indicate an irritation of distant portions as the stomach, liver, spleen etc. These are sometimes called sympathetic coughs. Sneezing represents a deep inspiration followed by a strong expiration through the nose. The opening from the larynx into the mouth being closed. It is generally a reflex action resulting from the irritation of the nasal branches of the fifth pair of cranial nerves. In case of sneezing produced by a brilliant light, the optic nerve is the afferent nerve. When the act itself is coming on, manifested by premonitory signs, it may be stopped by the firm pressure of the finger against the upper lip or the close pressure of the lower against the upper lip. In laughing there is an inspiration succeeded by a number of spasmodic and interrupted expirations, the glottis being open and the vocal cords freely vibrating at each expiratory movement. The expirations are less forceful than in coughing, the mouth is open and the muscles of expression give to the face their characteristic happy expression. In the case of crying the movements of respiration are somewhat similarly modified as in laughing, making it easy to pass from one to the other. They differ, however, in the rhythmical movements and the face expressions. Accompanying crying is the tear secretory process. In sobbing, which sometimes follows crying, there is a series of convulsive inspirations, the glottis being partially closed so that little if any air passes into the chest. In sighing, there is a long and deep inspiration largely through the nose followed by an expiration of shorter duration. Yawning is also a deep inspiration during which the mouth is open, usually accompanied by muscular contraction of the back and the lowering of the under jaw. It is followed by a short expiration.

Changes of the Air in Respiration:—It is only in comparatively recent times that the necessity of fresh air was rec-

ognized as necessary for life. At the beginning of this century expired air was found to have lost oxygen, to have gained carbon-dioxide and aqueous vapor and to have become warm. Many researches have been made with the object of discovering the amounts of these substances. The method used has been to draw through a chamber in which the animal is placed a continuous current of of air whose amount and composition is known. While the air is in the bronchial tubes the tidal air makes certain interchanges with the air inside these vessels. In an ordinary inspiration thirty cubic inches or 500 cubic centimeters of air rushes into the upper part of the pulmonary passages pushing as it were before it the air already in the lungs which is called the stationary air, amounting to about 200 cubic inches.

Diffusion now takes place between the new or tidal air and the stationary air, oxygen diffusing from the former downward into the latter while carbon dioxide diffuses in the opposite direction. At the next expiration following the inspiration 500 cubic centimeters of air is expelled, 17 cubic inches or 170 cubic centimeters of this is estimated being part of the air taken in at the immediate preceding inspiration, the remaining 330 cubic centimeters being vitiated air returning from the lungs. Hence, of the 500 cubic centimeters taken into the respiratory tract by an inspiration, 330 cubic centimeters remain in the pulmonary system gradually passing by diffusion down to the air cells, reaching these in the time occupied by five inspirations. In the expired air the first portions expelled are atmospheric air while the corporations of carbon dioxide and aqueous vapor gradually increase in the air, which is expelled in the later stages of expiration. The temperature of expired air varies, but usually it is slightly above that of inspired air. When the atmosphere is 20 degrees centigrade, the temperature of expired air in the mouth is about 34 degrees and in the nose 35 1-2 degrees. If the temperature of the air sinks low, the expired air falls slightly, e. g. at minus 7 degrees C. the expired air is about 29 degrees of the air temperature as high expired air becomes cooler than inspired air, e. g. at 40 degrees C. expired air is 37 degrees C. Expired air usually follows blood temperature depending upon the relation of the blood temperature to the atmosphere and the breathing rate. The change taking place, not in the lungs but in the upper respiratories. The average composition of atmospheric air is about as follows:

In 100 volumes there is of O, 20.90; N, 78.20; $CO_2$, .05; $H_2O$, (vapor) .85. There are also slight quantities of nitric acid, carburetted hydrogen, ammonia, inorganic and organic substances. The aqueous vapor depends upon the temperature. being higher with a higher temperature. The moisture like the heat is imparted to it, not in the lungs, but in the upper respiratory. The differene between inspired and expired air may be stated as follows:

Inspired air:

1. O, about 20.81 per cent.
2. N, about 79 per cent.
3. $CO_2$, about .04 or .05 per cent.
4. N, H and the organic properties vary with situation, etc.

Expired air:

1. O decreased to about 16.03 per cent.
2. N increased to 79.5 per cent.

3. $CO_2$ increased to 4 or 5 per cent.
4. It is saturated with aqueous vapor and contains a quantity of organic matter which gives the odor to the breath, some of which are poisonous.

An atmosphere containing 1 per cent. of $CO_2$ is far less hurtful than one containing the same proportions of $CO_2$ added as a result of the respiration of living organisms in the atmosphere. In one breath the air has more $CO^2$ and less O at the close than at the beginning of the breath. Hence if the breath is held long and there is a longer pause between inspiration and expiration the amount of $CO_2$ is greater in the expired air. In the case of expired air as compared with inspired we note (1) It contains almost 5 per cent less oxygen, (2) it contains 100 times more $CO_2$. (3.) It contains about .05 morenitrogen. (4). It is generally hotter, the temperature of expired air being usually about 37 degrees. (5) It contains sometimes ammonia, carburetted hydrogen.

The amount of air expired at any one respiration is the same as that inspired, but the volume of the expired air may be slightly greater, but this is due to the expansion of expired air resulting from an increased temperature. If both are measured at the same temperature and pressure the volume of the expired air is slightly less than that of the inspired, amounting to about one fortieth to one fiftieth of the whole volume. This is due to the fact that all the oxygen taken in during inspiration does not appear in the expired air as $CO_2$, some being retained and entering into the formation of other combinations. It is estimated that from 800 to 2000 grams of $H_2O$ are given off by the expiration process in 24 hours. It is believed that the larger amount of this comes from the moist walls of the upper respiratories. This is concluded from the fact that a dry air when inspired becomes quickly moistened in passing through these passages. This gives us the result that the air expired is saturated with vapor. That the volume of expired air is smaller than that inspired. It is estimated that 700 grams of oxygen are absorbed and 900 grams of $CO_2$ are eliminated in 24 hours. This amount of $CO_2$ represents 344 grams of carbon and 656 grams of oxygen, so that subtracting this from the 700 grams absorbed, we have 44 grams of oxygen disappearing through the body These numbers are subject to wide variations. Foster states that in his observations $CO_2$ varied from 686 to 1285 grams, and O from 594 to 1072 grams. These variations depend largely upon nutrition. The amount of $CO_2$ eliminated is increased by rapid and deep breathing. It is less during sleep and greater in middle age than the young or aged. Muscular activity and an increased amount of carbon in the diet will increase the amount of CO excreted. The principles of ventilation demand a proper proportion of O and CO .

If an animal is placed in a limited space without any air renewal the air gradually loses its O and becomes more fully charged with $CO_2$. If the proportion of O does not fall below 15 per cent respiration remains normal; from 15 to 7 per cent; from 7 to 4 per cent it becomes very difficult; under 4 per cent it is liable to result in asphyxia. When the body dies the blood contains O and this O is absorbed into the tissues. In addition to the absence of O there is the

presence of $CO_2$. Air suitable for breathing should not contain more than .07 per cent of $CO_2$. Other gasses are given off from the body much as carburetted and sulphuric hydrogen and volitile acids which give to the atmosphere its stuffy character arising from lack of ventilation. It is estimated that for efficient ventilation taking into account the size of the individual, the size of the room and the activity of the person 2000 cubic feet of fresh air should be supplied per head per hour. In cases of muscular activity more than this would be required. When persons are limited to certain apartments every person should have 1000 cubic feet. The floor room should be at least 1-10 of this and fresh air should be introduced hourly. The ventilation of the lungs artificially is of considerable importance. The trachea is exposed and a tube inserted into it through which air is forced periodically into the lungs by the use of bellows or a pump. Some instruments not only cause air to inspire but also alternately to expire from the lungs. The periodical inspiration is called positive ventilation; the expiration is called negative ventilation and the two processes alternated compound ventilation. In the human subject these methods are very dangerous as the continuance of positive ventilation produces cerebral æmemia, fall of blood pressure and of body heat. Hall and Sylvester have described the most commonly adopted methods. Hall's method is to put the patient on his face, supporting the chest upon a pillow, then turn the body gently a little beyond the side position, then quickly turn the body back on the face, repeating this process about fifteen times per minute. Raising the body on the chest expires the air. When the body is raised on its side the air is expired freely. At each turn of the body on the face pressure is brought to bear upon the back below the shoulder blades. The pressure to be removed before turning the body again on its side. Sylvester's plan is different. The patient is placed on his back on a solid flat surface with the head inclined slightly downward, a pillow or small support being placed beneath the shoulder blades. The tongue is then pulled forward beyond the lips and by the use of an elastic band around the chin and elongated tongue kept in this position, then from the patient's head siezing the arms just above the elbows they are drawn gently above the head and kept in this position for two or three seconds then the arms are turned and pressed closely against the sides of the chest for two or three seconds. These movements are repeated about fifteen times a minute until active respiratory action takes place in the body.

Changes in the Blood During Respiration:—As the blood leaves the right ventricle it is venous, when it is brought back to the left auricle it is arterial, of a bright scarlet color, which is the difference between arterial and venous blood. In passing through the pulmonary capillaries, that is pulmonary respiration, the blood changes from the dark purple to the bright scarlet, it loses $CO_2$ and gains oxygen. In passing through the systemic capillaries in the various tissues of the body, that is in internal respiration, the reverse takes place, the blood loses oxygen and gains $CO_2$ hence it changes from the bright scarlet to the dark purple. The exact nature of the changes in the pulmonary

alveoli is not easily determined. It would seem however that the pulmonary epithelium does not perform any special function of absorption or secretion and that the interchanges between the gases of the blood and the gases contained in pulmonary alveoli is determined by the law of partial pressure. Oxygen passes from the air cells into the blood because the tension of the oxygen in the former is greater than in the latter (the blood) which reaches the lungs through the pulmonary artery, while the tension of the $CO_2$ in this fluid is greater than the gases in the air cells. Hence $CO_2$ escapes from the blood in the pulmonary capillaries and not in the air cells. Oxygen is passing into the blood both in inspiration and in expiration, especially during the former. $CO_2$ is escaping from the blood in inspiration and in calm expiration, but not in deep inspiration. Venous blood becomes arterial if exposed to the air or mixed with oxygen, whereas arterial blood will become venous in appearance if kept in a closed vessel or subjected to a current of nitrogen or hydrogen. The chief difference therefore between venous and arterial blood is the amount of oxygen and $CO_2$ contained in each. The other differences are dependent upon their main differences. The ordinary air pump is not sufficient to extract the gas from the blood. Pflugers mercurial pump is a convenient arrangement. It consists of a long barometric tube, the upper part opening into a mercurial globe, with the upper part of which two tubes are connected, one vertical and one horizontal, the former communicating with the air and the latter opening into a glass receiver into which the blood is placed. At the openings of these two tubes into the globe there are stop cocks. From the lower end of the barometric tube a rubber tube passes to another globe of larger capacity than the first globe. This larger globe may be raised or lowered by means of a crank arrangement, the object being to extract the air out of the blood receiver very rapidly. After the air has been removed the blood is put into the air receiver freed from air. The blood gases under a maximum pressure now escape. They pass into the small globe from which they are driven through the vertical tube and are gathered in graduated tubes. By graduation the amount of gas per volume of blood is measured. The total amount of each gas is estimated by volumetric analysis. The percentage of the gases obtained from the two kinds of blood is measured at 0° C. and 760 mm. barometric pressure are found to be: in one hundred volumes of blood,

| | O | $CO_2$ | N |
|---|---|---|---|
| Arterial | 20 | 29–40 | 1-2 |
| Venous | 8–12 | 46 | 1-2 |

That is arterial blood as compared with venous blood contains from 8 to 12 p. c. more oxgen, 6 p. c. less $CO_2$. Some physiologists say 8 p. c. less of $CO_2$. In the case of arterial blood there is little variation in the arterial system, while in venous blood differences occur according to the location of the vessels. For example, venous blood from an active secretory gland is almost identical with arterial blood, while the gland is not active the blood is characteristically venous. Two theories of respiration have been advanced by physiologists to account for the interchanges between the blood and the air. The combustion theory ascribed to the process of combustion in

the lungs the production of carbonic acid and aqueous vapor. The secretory theory denies that there is any combustion, whereas the oxygen became absorbed in the lungs and became diffused through the other tissues, the carbonic acid being secreted in these, absorbed in the blood carried to the lungs and given off. Recent investigations in connection with the gases of the blood and the temperature of the blood as found in the right and left sides of the heart have given predominance to the secretory theory. Gaseous masses, unlike the solid and fluid masses, have no form, but consist of a large number of molecules tending to separate from ohe another on account of mutual repulsions. Hence if two gases meet they will easily intermingle until an exact quantity of each gas enters the combination. The melecular repulsion is called the gas pressure or tension, the greater the molecules the greater the tension. Hence the law of gases is that the pressure is in inverse proportion to the density of the gases. Fluids also absorb gases. If some ammonia gas be placed in contact with water, the water rapidly absorbs it. The higer the temperature of the water is raised it absorbs less of the gas, when it reaches boiling point no gas is absorbed because the water itself becomes gas. The co-efficient of absorption in the case of a fluid for a gas is, according to Bunsen, the number representing the gas volume, reduced to 0 ° C at 760 mm. B. M. pressure, taken up by one volume of fluid. The volume of gas absorbed rises and falls in proportion to the pressure. If an atmosphere above a fluid consists of two or more gases, absorption takes place in proportion to the pressure each gas would have if alone in the place of the mixed gases. This pressue is called the partial pressure of gas, accordin[illegible] [illegible]unsen. The partial pressure there[illegible] [illegible]epends upon the volume of each gas in the combination of gases, e. g. each gas forming an element in a mixture exerts a pressure equal to its proportion of the mixture, i. e. if atmospheric gas is under pressure of 760 mm.

In air we find 20 volumes p. c. of O, and N. 79 volumes p. c. Therefore the partial pressnre of O would be 760 times 20 divided by 100 equal 152 mm., of N. 760 times 79 divided by 100 equal 600.4 mm., $CO_2$ would be 760 times .04 divided by 100 equal 30.4 mm. By using these results in connection with arterial and venous blood we find (1) that both kinds of blood contain O, $CO_2$ and N. (2) The difference between arterial and venous blood is in the amount of O and $CO_2$. (3)The gasses are dissolved in the blood so that respiration is simply a process of diffusion, $CO_2$ passing out and O passing in according to the law of pressure, Three important elements enter into the process of respiration, (1) the inspiratory and expiratory motions causing a partial mixture of the air, (2) subsibiary movements, such as the heart beats and (3) the diffusion of O and $CO_2$ depending upon the law of partial pressure. The venous blood co[illegible]ain[illegible]g $CO_2$ at blood temperature and with a certain pressure enters the pulmonary capillaries distributed over the walls of the alveoli in the lungs. These air cells are filled with air at a certain pressure and temperature. If the pressure of $CO_2$ in the blood is greater than that in of $CO_2$ in the air vesicles, $CO_2$ will pass from the blood until equilibrium is restored. Sim-

ilarly if the pressure of O in the blood is greater than that in the air cells, O will be absorbed until eqilibrium is produced. This is true if the gases are simply dissolved in the blood. But the gases exist in the blood rather in a state of loose chemical combination. As a result the amount of oxygen absorbed does not vary greatly with the pressure, but decreases in the case of temperatures below the atmospheric pressure, and increases in pressure above it. This fact is proved by the observation that blood serum does not absorb much more O than does water. and defiberinated blood absorbs oxygen, the amount depending not upon the pressure but on the amount of pure hæmoglobin. Similarly $CO^2$ is a state of loose chemical combination, only a small quantity being subject to partial pressure. This of course would be explicable on the secretory theory that the pulmonary membrane is actively engagin a secretory process. The gases of the blood then instead of existing in a simple solution are largely in combination with certain elements of the blood so that the escape from the blood is a process of disassociation. Only a small quantity of oxygen is absorbed according to the law of pressure, the great mass of it being in combination with haemoglobin. On the other hand the carbonic acid seems to be associated with the substances in the blood plasma and that its disassociation is connected with some substance in the red corpuscles. Heamoglobin when united with oxygen is called oxyhaemoglobin. Haemoglobin is an amorphus or crystalline, very soluble in water. Crystallized haemoglobin readily absorbs and holds in combination a quantity of oxygen equal to that found in a volume of blood containing the same amount of haemoglobin. This gives us a special function for the red corpuscles in respiration. The haemoglobin of the blood in the pulmonary artery absorbs oxygen, becoming oxyhaemoglobin, carrying it to the tissues, where the oxyhaemoglobin is reduced. Thus the coloring matter of the red corpuscles are constantly carrying oxygen from the lungs to the tissues, the association and disassociation taking place without destroying the haemoglobin. In regard to $CO_2$ our knowledge is less deffinite. Blood serum yields about 30 volumes per cent of $CO_2$; defibribate blood yielding about 40 volumes p. c., the yield of a little more $CO_2$ from the same amount of defibrinated blood than in the same of serum being supposed due to something which acts like an acid. There must be some chemical substances for the absorption of the $CO_2$ of the blood. Some have suggested plasma albumin. But as yet this subject remains for fuller investigation Probably what takes place is, that the air inspired is in someway separated in the air cells of the lungs by the fine epithelial cells and the endothelial walls of the pulmonary capillaries from the blood circulating in them. This interchange is through the fine porous membrane. The oxygen is loosely bound to the corpuscles, hence the law of diffusion applies only in so far as it must pass into the liquor sanguinis so as to get the corpuscles The corpuscles of the venous blood return from the tissues with reduced haemoglobin. Oxygen enters the plasma from the air and the haemoglobin at once takes up a fresh supply. This is evident from the fact that in high altitudes as well as in deep mines the health of the blood is not materially altered al-

though the pressure rises and falls considerably for the oxygen exists in a loose chemical combination apart from partial pressure. In the case of carbonic acid as is found in the plasma, a small part is absorbed and a large part chemically bound together with sodium phosphate. in the air carbonic acid is found only in traces.

The air of lungs is never wholely expelled. Hence the mixture of respired air with the air of the air makes the latter richer in oxygen and poor in carbonic acid, although there is more carbonic acid than in an atmospheric air. The pressure of carbonic acid in venous blood is found to be almost 50 p. c. more than that of the air cells. Carbonic acid will pass from the blood into these air cells till equilibrium is attained. Before this has been attained however expiration has driven out a portion of the air so that the pressure of the carbonic acid again becomes less than the blood. The constant diffusion between the pulmonary blood and the air cells keeps up a steady process.

Respiration in the Tissues:—What takes place in the pulmonary capillaries in connection with the air cells, also happens in systemic capillaries through the tissues, except that the comparative tension of the O and $CO^2$ within and without vessels in the tissues are just the reverse of those found in the lungs. The tension of the O in the tissues is extremely low for this gas does not remain free in the tissues, but at once enters into combination with the tissue elements. Hence the tension of the O in the blood is much greater than it is in the tissues and this gas therefore freely escapes from the former into the latter. On the other hand the tension of the $CO^2$ in the tissues is greater than that of the tension of the $CO_2$ in the arterial blood. $Co^2$ therefore passes from the tissues into the blood changing the blood from a light scarlet to a deep purple color. The pressure of the $CO_2$ in the lymph is smaller than that of venous blood. It remains difficult to understand how the venous blood can absorb carbonic acid. The lymph however has modified its pressure by contact with arterial blood both in the tissues and lymphatics. The CO is set free, then absorbed by the blood, loosely combining with the carbonates and the phosphates of the blood. The respiratory quotient which represents the proportion between the amounts of oxygen absorbed and the quantity of $CO_2$ developed in the case of the human subject is placed at .87.

Pure air at the ordinary pressure and of the ordinary composition is necessary to normal respiration. The respiratory mechanism can adopt itself to abnormal conditions within certain limits. Nitrogen or hydrogen may be breathed without any dangerous results if a sufficient amount of oxygen is present. Pure hydrogen or nitrogen, when breathed quickly proves fatal for lack of oxygen; and such gases as hydrocholoric, sulphurous and nitric acid or ammonia cannot be inspired because they result in a spasmodic closure of the glottis, producing at the same time irritation of the respiratories. Other gases like carbolic acid, carbonic oxide, sulphurretted hydrogen, etc., enter into the lungs and produce dangerous results from interference with the normal respiration, or have some poisonous effect on the tissues. Inspiration of $CO_2$ results fatally in a very short time

but 25 to 30 p. c. in the air does not prove fatal if not continued for more than a few minutes. Carbon monoxide is a very poisonous gas destroying life when found to the extent of 1 p. c. It combines with haemoglobin so that it is prevented from performing its function in connection with the carrying of oxygen. The blood under its influence turns into a very bright scarlet color; .001 p. c. in the air will effect the breathing, and it is found that if 60 p. c. of the haemoglobin is combined with carbon monoxide, the heart's action is affected, respiration is weakened, and death gradually ensues. Nitrogen monoxide mixed with oxygen in the ratio of 2 to 1 may be breathed so as to induce intoxication. This is called laughing gas. If breathed in its purity it results in asphyxia. Sulphurated hydrogen mixed with air to the extent of 4 p. c. causes the blood to become greenish and results fatally. Certain expressions are used to denote peculiarities associated with respiration.

Apnoea represents a state in which the respiratory movements are suspended. It may result from quickly repeated inspirations of air in which case the suspension takes place for a few minutes. In the case of artificial respiration, especially individuals subjected to tracheotomy, if the lungs are repeatedly filled with air and then stopped, apnoea follows. After a short rest respiration begins very feebly and gradually returns normal. The cause was formally supposed to be found in the excessive amount of oxygen in the blood and the lack of $CO_2$. That there is something in this cause is apparent from the fact that respiring pure O it becomes more marked than in respiring pure air. To answer this it has been shown that by filling the lungs with oxygen apnoea may be produced, but not of such a marked kind. This difference in the apnoeic pause has led to the conclusion that it is due to the excessive storage of oxygen in the air cells, thus rendering respiration unnecessary. The fact that hydrogen produces the apnoea and that if the vagi nerves be cut hydrogen filling the lungs causes violent dyspnoea, whereas flation of the lungs with air produces no result, seems to suggest that the repeated respiration stimulates the pulmonary peripheries of the vagus nerves producing impulses which inhibit the respiratory center, by depressing it and so preventing the respiratory action.

Dyspnoea, or Difficulty of Breathing:—It is generally found accompanied by slow and forced respiration. There are different forms of it. From some cause sufficient oxygen does not enter the blood which therefore becomes unduly venous. Hence the respiratory center is strongly stimulated and violent inspirations and expirations follow. There is a form of dyspnoea due to the existence of certain substances in the blood derived from the muscles during active operation. Dyspnoea may result either from deficiency of O, or excess of $CO_2$, or both may be combined to produce it In the case of confinement in a small space where the O is limited, or when it is filled with hydrogen. It may result from breathing an air containing a large quantity of $CO_2$, even though more than the regular amount of oxygen be present, and even though the blood contains less than the normal quantity of $CO_2$. For example: If a person be forced to breathe air containing 10 p. c. of $CO_2$ dyspnoea results, although there be sufficient O

present both in the blood and air. If an animal breathed N the result is that the respirations become frequent and the inspirations are strong. In the case of breathing an air laden with $CO_2$ the respiration becomes slower and are marked by strong expirations. This strong increase in the depth of respiration is due not only to direct action upon the respiratory center, but to reflex actions upon the center conveyed through the sensory nerves of the larger bronchi. Hence the depth of respiration in connection with inhilation of excessive $CO_2$ arises from the stimilation of sensory nerves in the bronchial mucous membrane. In case of the inhilation of air deficient in O, the inhilation of $CO_2$ is not affected. It is marked by increased blood pressure which continues for a considerable time before death takes place, death being preceeded by certain disturbances in motor activity, such as is not found in the case of death resulting from the excessive inhilation of $CO_2$. The difference between the inhilation of excessive $CO_2$ and deficient O air is explained in connecting with the blood. The blood deficient in O influcuces the respiratory center, whereas blood with an excess of $CO^2$ affects the expiratory center. During the contraction of the muscles certain substances are formed which affect the respiratory center, accompanied by muscular activity there is an increase in the respiratory activity and in the case of strong muscular action dyspnoea results. These products of muscular action pass to the blood and the blood acts as a stimulant upon the respiratory center. The substances are probably of an acid nature and are broken up in the blood, being carried through the system in the circulation. If the blood that flows to the brain is higher than the normal temperature it may result in dyspnoea. In fact any thing that weakens the circulation or diminishes the amount of haemoglobin in the blood causes dyspnoea. This accounts for the fact that people with heart trouble or suffering from anemia become so dyspnoeic with the heart's over exertion. Similarly any thing that tends to prevent the interchange of O and the excretion of $CO_2$ assists if it does not produce dyspnoea. Hence pneumoniaic persons and those affected with lung tuberculocis are subject to it by slight over activity. It is characterized in general by an increase in the frequency and depth of the respiratory movements. Hence the ordinary muscles of respiration, diaphragm, intercostals, especially the external, are assisted by the scaleni and seratus posticus. The ribs become elevated and depressed and the larynx which normally is resting in respiration is forced up and down considerably. Hence, dyspnoea may be caused (1) by a puncture opening into the pleural cavity. (2) by excessive hemorrhage, the blood loss affecting the ordinary activity of the respiratory center. (3) diminishing the circulation of the blood, at least in the brain, so that the brain does not receive a blood supply sufficient to keep it in active operation. (4) Anything that prevents the normal passage of air to or from the lungs as in case of strangulation. (5) congested condition of the lungs which lessens the respiratory action by reducing the extent of the respiratory surface.

ASPHYXIA :—Literally this means without pulse, but it is applied to that state in which there is a cessation of respira-

tory rhythm, due to exhaustion of the respiratory center. It results from the interruption of the process of respiration caused by deprivation of air, as, for example, by placing an animal in a confined space so as to lead to an increase of $CO^2$ in the blood It may take place suddenly as in the case of complete blocking of the trachea, or it may come on gradually. In any case it is divided usually into three stages. (1) During the first stage we find difficulty of breathing. The respirations are rapid, irregular and soon become deep and labored. The muscles of inspiration are subjected to very strong contraction and those muscles in the chest and abdomen which are connected with respiration contract powfully at intervals. After a brief space this intermittent contraction passes to the muscles of the lower parts of the body, chiefly the flexor muscles. (2) The violent convulsions give place to deep and slow expiratory movements The inspiratory center ceases to be effected to any great extent and inspiratory movements become weak, whereas the expiratory center is strongly nerved, resulting in very strong intermittent respiration. This second stage, like the first, continues about one minute; during these two periods the blood becomes deficient in Oxygen, resulting in the blue discoloration of skin, lips and gums. The blood has become more venous, resulting in strong stimulation of the cardio-inhibatory center, causing the hearts action in contracting to be sensibly diminished. The respiratory centers in the medulla are excited and in the latter part of the second period at least the spinal cord is also strongly excited, vaso-constrictor center causing constriction in the capillaries and a rise of the pressure of the blood.

During this period general exhaustion follows, resulting in collapse, coma. The inspiratory muscles act weakly and only intermittently, while the expiratory muscles give occasional spasmodic contractions, resulting in convulsions. Similarly the muscles of the lower extremities become spasmodically convulsive, chiefly the extensors, gasping being associated with sharp, short expirations. The pupils become dilated, the lids of the eyes do not close when the balls are touched, consciousness disappears, reflex actions cease. After the body becomes arched backwards, especially the head and lower extremities, the nostrils being expanded, the heart is paralysed, the right auricle and ventricle being dilated on account of the free flow of venous blood, while the muscular tissues become enfeebled, loose and flaccid. Finally the heart ceases to beat, the respiratory centers becoming completly paralysed. This period lasts from four to five minutes. The heart however continues beating feebly for some minutes after the respiratory actions cease. If artificial respiration is induced before cessation of the heat's beating the respiratory movements may be restored and other functions revived. If death results from obstruction of the trachea the three periods last about five minutes. If it comes on gradually death comes more slowly and may result without any disturbance of motor activity. In case of death by drowning, complete submersion for a few minutes results fatally, death resulting either from suspended respiration or failure of the heart's action. It is harder to revive persons who have been submerged in water than those who have weakened on account simply of lack of

oxgen. It is said that resuscitation is impossible after submersion five minutes. Newly born children are able to sustain life longer in case of submersion than adults. After birth on examining the body, the blood is found very dark, nearly black in some cases, the auricle and ventricle on the right side of the heart and the lungs together with veins being gorged with their venous blood, whereas the arteries are almost if not entirely empty of blood. This is due to the forcing of the blood on into the venous circulation by the elasticity of the large vessels. During the first and second periods the pressure of the blood increases, the smaller vessels contracting due to the stimulation of the vaso motor center, increasing the peripheral resistance. The heart's action becomes stronger although its beats are less numerous, each beat being more forcible. After this the heart action becomes more feeble on account of the large quantity of venous blood in the heart, the left ventricle being unable to force the blood out against the force of the peripheral resistance. At this point the blood pressure falls to its lowest point, marking the beginning of the third stage, on account of the paralysis of the vaso-motor center. The venous blood gorges to the right side of the heart injuring the cardiac muscle and enfeebling the left ventricle, diminishing peripheral resistance which results in complete collapse.

Innervation of Respiration:—Pulmonary respiration as we have said is carried on by means of action of a number of muscles, some of which are in position widely separated from each other, but all of which act together in a co-ordinate manner. The movements are carried on involuntarily. These muscular actions are all controlled by a nerve center, situated in the hinder part of the floor of the fourth ventricle. In addition to this great center, other centers of lesser importance have been spoken of in connection with the spinal cord, these being called subordinate centers. In connection with the respiratory center there are certain nerves that bear impulses to and from the center.

Respiratory Centers:—All the brain except the medulla may be removed and yet the respiratory movements will continue. If however the lower part of the brain be destroyed the respiratory rythm ceases. Respiration continues normally after a section of the spinal cord below the beginning of the phrenic nerves. Flourens by such experiments concluded that the center is in the medulla at the extremity of the V in the gray matter in the floor of the fourth ventricle. He located it in a region 5 mm. in diameter between the nuclei of the vagi and the spinal accessory nerves. The destruction of this portion was found to result fatally and hence it was called the vital knot. Later researches have modified these conclusions.

It was found that the area of Flourens vital knot consisted not of a center but rather of a group of nerve fibres arising from the roots of the vagi, spinal accessory, trigeminal and glosso-pharyngeal nerves. It was shown that the removal of the vital knot was not of necessity fatal and later it was found that respiration was not suspended either by section of the spinal cord below the medulla or by division of the medulla below the calamus scriptorius. The stimulation of the vital knot does not excite respiratory act-

ivity but simply influences the character of the action of the diaphragm. Without locating the center exactly it seems that there is a center in the lower part of the medulla. This center consists of two parts one on each side of the median line, the two parts being closely connected together by means of commissures. The two halves act simultaneously, being connected with the lungs and respiratory muscles on the respective sides. If the median line be divided the two parts act simultaneously, whereas if the side part be destroyed suspension follows in the case of respiration on that side. If after dividing the median line, one of the vagi is divided also no impulses reach the centre on that side from the lungs, whereas if the median line be left intact stimulation of one of the vagi affects both sides, and stimulation of the central end of one of the cut vagi tends to increase the activity of both sides. Thus the two sides act together as a single centre. Each central half is supposed to consist of two parts, the one an inspiratory center controlling the inspiratory muscles and the other an expiratory center controlling the expiratory muscles. This connection is of such a nature as to give to the inspiratory center augmentor action and to the expiratory center an inhibitory action. It the case of stimulation of both the inspiratory and expiratory centres the acceleration overbears the inhibitory, giving to the whole respiratory center a peculiar acceleratory activity. Some writers claim that there is a respiratory center or centers in the spinal cord, acting automatically and by reflex action from the periphery Others have claimed that higher centers exist in the brain. One has been located in the prominence of the gray matter of tne brain between the optic tract and corpora albicantia associated with violent respirations upon stimulation. Another center has been located in the two anterior bodies of the corpora quadrigemina associated with expiratory action. An inspiratory center is claimed in the posterior bodies of the corpora quadrigemina and in the upper part of the pons varolii, acting as an inspiratory center. Others claim that in the lateral wall of the third ventricle is a center which deepens respiration by stimulation. There is no satisfactory reason however to establish any of these as true centres. Even if there are centres, it is possible that they are entirely subordinate to the center in the medulla. In order to establish any of these as independent centers it would have to be proved that the injury or removal of these centers would result in stopping or modifying respiration and also that there are nerves connected with the respiratory organs and muscles leading to these centres. Respiratory centers have also been located in the spinal cord, chiefly for the reason that after dividing the spinal cord from the brain respiratory movements continue at least for some time. But the respirations in such cases are irregular and rather spasms than respirations of a normal character. It has been observed that if the medulla be separated from the influence of all afferent nerves by cutting it under the corpora quadrigemina and also dividing the vagi and the posterior roots of the spinal nerves, respiration continues, but these assume a spasmodic form. Thus by automatic activity the medulla can produce spasmodic actions. Normally however it is subject to afferent impressions, so that normal

respiration depends upon reflex action. The rhythmic action of the center of respiration is communicated by means of impulses to the respiratory movements. This power of producing the rhythm is inherent in the center if not entirely, to a large extent, not being caused by external stimulation, so that the center is automatic to extenal stimuli. It is not so, in relation to the blood, for when the centre is in isolation from afferent impulses, the activity is continued on account of the stimulation of the blood. The activity of the center may be modified by influences reaching it from higher centers, for example, the effects of various mental states and emotions, upon respiratory movement is well known and the effects of the will, for the respiratory rhythm may be voluntarily altered both in character and rate.

The respiratory centre is thus not a voluntary centre, although it may be influenced by the activity of the higher voluntary centres. As the action of the respiratory centre still continues when the afferent nerves leading to it are divided the centre cannot be properly a reflex one. It must be an automatic centre. Yet though the activity of the centre does not depend upon reflex stimulation, its action may be and continually is influenced by impressions reaching it along afferent nerve paths. If the vagus nerve be cut the respiratory movements become slow and deep, the pause in each respiration being markedly prolonged. These effects are greatly increased if both the vagi nerves be cut. The stimulation of the cut end of the central portion of the vagus nerves restores the normal rapidity and character of the respiratory rhythm, and if the stimulus be sufficiently strong causes the diaphragm and other inspiratory muscles to pass into a state of tetanus, so that respirstion is suspended in a state of deep inspiration. From this it is evident that under ordinary circumstances influences are continuously ascending the vagi and quickening the action of the automatic respiratory centre. The rhythm of respiration includes a rhythm of inspiration and expiration. Normally in inspiration we have the muscular action, whereas in expiration there is very little of muscular movement. Yet in labored expiration muscular activity comes into full play. Thus there is an alternation between inspiration and expiration, more marked when it becomes deep. Some think that in the vagus are to be found fibres connected both with the inspiratory and expiratory centre, alternating in the carrying of influences to the centres. But that inspiration and expiration take place alternately without such a connection is evident from the fact that section of the vagus and the consequent separation of the centre from its action the alternation of these respiratory movements still continues. The rhythm of the inspiratory movement is dependent therefore upon the respiratory centre whose activity is sustained by its relation to the blood flow and that rate as well as character of the respiratory movements depend upon the complexity of influences which may, and continuously do affect the centre. The respiratory centre is subject to the influence of (1) higher centers (2) of the afferent nerves (3) the blood. (1) There is an influence exerted upon the respiratory centre by the higher centres. Strong excitations of any of these special

sense nerves influences respiration, e. g. the optic and auditory nerves on stimulation result in inspiration and of the olfactory in expiration impulses. Powerful excitation of the sensory fibres of the 5th cranial nerve as in the case of sneezing results in expiratory motions. All the sensory nerves of the head act in such a way conveying impulses to the brain. If the medulla be divided high up on the floor of the 4th ventricle so as to divide it from the brain, respiration ceases for a few minutes and then may resume again, the breathing going on as before, except as to the extent of the movements, which varies as in the case of sleep. If a transverse division is made lower, respiration becomes forced, and if the incision takes place at the point of the calamus scriptorius. the respirations become periodic with long pauses, gradually diminishing in force. By the stimulation of the sensory cutaneous nerves this periodisity was renewed and normal restoration restored. This gives some light upon the abnormal condition of respiration found in certain diseased conditions of the heart and lungs in which breathing becomes periodical, with long pauses lasting about .8 of a minute, succeeded by superficial respirations becoming deeper and deeper until the series of of about twenty respirations is completed, when a new series starts of the same character. In this case the pause may be shortened by arousing the interest of the patient and also the section of the vagi cause these periodic breathings to give place to spasmodic breathing. Hence periodic respiration arises when the higher nervous centers are in a condition of lethargy, either inactive or failing to send down impressions from above to the lower centres among which the respiratory centre is found. (2) Afferent nerves. These nerves are the vagi, the glosso pharyngeal, the trigeminal and the cutaneous nerve. Impulses passing along the pneumogastrics have an important influence on the respiratory centre. Their action is most important in conection with this centre. Their influences can best be brought out with the section of these nerves and the effects produced by stimulation of various kinds. When the medulla has been separated from these higher centres if the vagi are divided there results a lengthened spasm of inspiration, followed by spasmodic inspiration and expiration, resulting in death. If the vagi are cut before the separation of the medulla from the higher centres, the respirations are at first normal, but becomes deeper and slower, followed by respiratory spasms. The absence of impulses passing through the vagi can therefore be made up by impressions arising in the brain and passing through the respiratory centres. If the impulses are suspended from one side the rhythm of the center is not affected, but if the impulses from both sides are suspended the center acts without any rhythm at all. The vagi and the upper parts of the brain are, therefore, media through which pass impulses that influence the respiratory rhythm, in the case of the vagi these impulses are constant, whereas in the upper parts they pass only intermittently. It is through this latter channel that the volitional and emotional and mental influences pass, as well as the impulses coming from the sense organ. The lungs send impulses along the vagi which affect the center in causing this discharge of energy. The excitation of

the vagus in the neck produces strong inspiration, and if the excitation become strong the inspiratory muscles may be thrown into tetanus. In some cases the strong stimulation of the vagns may produce expiratory activity according to the period of the respiratory rhythm at which the stimulation is applied. Hence the vagus contains both inspiratory and expiratory fibres, the impulse borne along the vagi so stimulating the respiratory centre that rhythmic liberation of energy takes place resulting in respiratory and expiratory movements. The vagus is thus in constant operation conveying these impressions from the lungs to the centre producing a discharge of energy which prevents the centre becoming overstocked. The center is thus influenced from below by the vagi, and from above by the upper centres. The division of one vagus may have no effect or only slightly effect the respiratory activity. These effects quickly pass off. If both vagi be divided the respiratory rhythm is diminished, followed by slow, deep inspirations, strong expirations and a pause between each inspiration and expiration. If the central ends of the divided nerves are irritated the inspiratory and expiratory impulses become more powerful. If the one vagus be divided and the central end of the cut nerve be stimulated different results follow, depending upon the character of the stimulation. Electric stimulation effects both inspiration and expiration, the chemical stimulation only the inspiration and mechanical stimulation only the expiratory. If the electric current is weak, inspiration is lessened and respiration lengthened; if the current is increased and respirations become more frequent and the inspirations deeper and stronger. If the vagi become exhausted by excessive stimulation, then the application of a stimulus to the central end of the cut nerve results in increased expiration, the inspirations being short and weak and the expirations long and deep, a pause occurring between them. If the irritation be made very strong, the respiration is arrested in expiration. These opposite results are due to two kinds of fibres, each fibre having its own function, the different fibres being effected differently under different degrees of stimulation. Both kinds of fibres carry impressions originating in the vagi peripheries in the lungs. The expiratory impulses, however, may arise in the laryngeal nerves, especially in the superior laryngeal. The superior laryngeal nerves are sensory branches of the vagi passing to the larynx. The excitation of these produce expirations and as the nerve fibres are very sensitive strong stimulation produces a stoppage of respiration with a tetanic condition of the muscles of expiration, e. g. the presence of irritant substances in the larynx immediately stops inspiration. When stimulation is weak respiration becomes slow, the pause is lengthened. If the stimulation is strong a rest of respiration takes place in expiration. These nerves seem to be expiratory nerves, acting as such even when the medulla is divided from the upper part of the brain. They do not act constantly like the vagi, but simply act temporarily when some irritation affects the larynx, impulses being originated that stop inspiration. The impulses which arise in the lungs originate from the mechanical stimulation of the lungs. Some think that the stimulation arises from the gases contained in the air

vesicles. According to this during expiration the $CO_2$ contained in the vesicles stimulates the inspiratory fibres terminating in the lungs, the impulse being carried to the inspiratory centre. On the other hand the dilation of the lungs during the act of inspiration stimulates the expiratory fibres terminating in the lungs arousing impulses carried to the expiratory centres. The mechanical lung movements, however, are stronger and originate the impulses which affect both inspiration and expiration. In the case of the glosso pharyngeal nerves, their division does not affect respiratory movements. Their stimulation is followed by an arrest of respiration for a time equal to three preceeding respirations. After the breathing commences with inspiration just from the point where the diaphragm was arrested. During the process of deglutition respiration is stopped, there is first a stimulation and after an inhibition, the stimulation taking place through the sensory nerves of the tongue and pharynx, and the inhibition through the glasso pharyngeal nerves. The inhibition of respiration makes it possible to swallow either food or drink without drawing them into the larynx. The stimulation that passes through the sensory nerves to the center excite the milohyoid muscles used in swallowing and then the inhibition takes place, so arresting the breathing as to prevent the blood from passing into the lungs. Nervous impulses seem to pass by irradiation from the deglutation centre to the respiratory centre causing a short inspiration followed by inhibition through the glosso pharyngeal during a longer period. As soon as the food is swallowed the inhibition ceases and respiration is restored. The tri-geminal nerves of the nose may be excited so as to cause arrest of respiration in the case of certain irritants, for example, certain gases, fumes, etc. Tobacco smoke, e. g. introduced into the nostril of a rabbit causes the stoppage of respiration. In the same way ammonia breathed through the nose results in arrest of breathing in expiration. Odors may similarly effect respiration through the olfactories. Respiration is also influenced through the centre by impulses conveyed along the cutaneous nerves. Slight stimulation has no very decided effect, but if the excitation is strong, there is first an increase in respiratory movements, followed by a number of deep inspirations and the sessation of expiration, e. g. sprinkling the body with cold water, plunged into a cold bath, excite inspirations by stimulating the sensory nerves of the skin. There are reflex impulses and they are more decidedly marked if the higher centres have been severed from the medulla, becoming distinctly spasms, passing into convulsions if the stimulation is very strong.

(3) The respiratory centre is also effected by the condition of blood through the influence that the blood exerts on the peripheral extremities of the vagus nerve distributed to the lungs. The activity of the center is also directly effected by the state of the blood. Various theories have been propounded historically as to the nature and causes of this influence. These theories have all been based on the idea that the stimulating cause of the respiratory movements is found in the gases in the blood in its circulation through the brain, both deficient oxygenation and excessive carbonization exciting the centre, the former producing in-

spiration and the latter expiration. This position is questioned by some, e. g. by Marckwald who says that the normal stimulation of the centre of respiration is not due to the deficient oxygenation of the blood or its excessive carbonization, as certain animals, such as the hybernating marmot, have been deprived of circulation without interfering with respiration. Respiration continues after a severe hemorrhage, the centre continuing active, depending for its nourishment upon the fluid found in the substance itself or lying between the different centres. When the anabolic process advances to a certain point, the substance itself yields to dissolution thereby setting free energy that produces spasmodic respiration. After this a still further process of anabolism follows, resulting in the same changes and so successively. During katabolism the branches of the vagi terminating in the lungs are active, producing by impulses sent to the center discharges which maintain the respiratory rhythm.

If the blood is more highly arterialized than is normal from any cause, e. g. by breathing an atmosphere too rich in oxygen the respirations are slowed, or even may be suspended. The person passes into an apnoeic state. If, on the other hand the blood is more venous in character than normal, e. g. from the air not being allowed to enter the lungs, from breathing an atmosphere containing too much $CO_2$, or from such excessive respiration as occurs in great muscular exertions, the respiratory movements become more rapid and also more violent. In addition various other muscular movements, as convulsions, may occur due to stimuli being sent from the respiratory centre to various other motor centres. This state of dyspnoea continues until the energy of the respiratory centre is exhausted, unless oxygen be introduced into the blood; after this exhaustion the respiratory movements gradually cease and the state of asphyxia supervenes. Evidently then the increase of oxygen with the diminution of $CO_2$ in the blood lessens, while the opposite condition increases the activity of the respiratory centre. A rise or fall in the temperature of the blood produces similar changes in respiration. Each successive breath is not determined by the blood condition in the brain at the time of breathing. The centre of respiration is automatic, at least to external stimulation. The rhythm of respiration depends upon certain molecular changes taking place during the metabolism of the substance. Any impulses that affect the center have an influence on this metobolism. The lack of oxygen and the excess of $CO_2$ affect in some way the complex processes of katabolism and anabolism, in the case of deficient oxygenation rendering the structure of the centre more unstabe and the case of excessive carbonization increasing its explosive character. The same is true of excessive muscular activity sending up to the medulla a blood so changed in character as to affect the centre, the blood leaving the muscle in the case of great muscular activity being more venous than normally. Venosity of the blood does not account for the change in the centre, for the blood that leaves the right side of the heart in great muscular activity, is not less oxygenated, but more oxygenated than usual. This has led to the suggestion that it is due to the presence in the blood of an acid like

sarcolactic acid, whereas it may be the respiratory center is affected through the blood. The respiratory centre may be influenced thus by impressions sent along efferent nerves, by some disturbance in the gaseous interchange in the lungs or by some changing the character of the blood that circulation through the brain, as to modify its metobolism in all these influences affecting the breathing and assisting in the adaptation of the respiratory mechanism to the bodily organism.

From the centre there are transmitted at regular intervals through various nerve fibres, nervous impulses which stimulate the different muscles of respiration. These impulses are doubtless sent through subsidiary centers situated in the spinal cord before they actually reach the particular nerves which supply the respiratory muscles and these subsidiary centres may in some exceptional cases carry on the stimulation of the respiratory muscles when the chief centre may be for some reason disabled. During respiration the only afferent nerves along which the nervous impulses that produce contraction of the muscles pass are the phrenics to the diaphragm, the intercostals to the intercostal muscles and the facial to the dilatores nasi. Division of one phrenic results in paralysis of that side of the diaphragm, division of both phrenics paralyzes the entire diaphragm. In this case inspiration is hindered because it depends entirely on the other muscles while the diaphragm is so relaxed as to be pulled into the chest at each inspiration, thus retarding the lung activity. If the spinal cord be divided beneath the junction of the 5th cervical nerve, the costal respiratory movements are suspended, In this case the phrenics are intact and hence diphragmatic action continues. If the division is made of the cord just above the phrenic organ both the costal and the diaphragm movements are arrested. During normal respiration influences are carried to the larynx causing the glottis to open during inspiration, these impulses passing along the laryngeal branches of the pheumogastrics. If the pneumogastrics are divided above the origin of these nerves, respiration ceases in the larynx, the laryngeal muscles being paralyzed and the glottis closed.

The nerves of the lungs are the vagi, the sympathetic and the upper dorsal nerves. The pneumogastric sends out branches into the lungs, these branches affecting the respiratory actions. It has been found that by excitation of one pneumogastric the bronchi of the lungs become constricted. On the section of one of the pneumogastrics the bronchi of that side are dilated, the stimulatinn of the peripheral and the central ends of the divided nerve produces a contraction of the bronhi on both sides, in the case of administration of either this stimulation produces dilation of the bronchi. This seems to indicate (1) the existence of afferent and efferent constrictor and dilator bronchi fibres in connection with the pneumogastrics and (2) that all these fibres pass through the pneumogastric (3) experiments have shown the existence of pressor fibres whose excitation produces constriction of the vessels of the lungs, the afferent pressors being in the vagi while the efferent fibres pass through the sympathetic to the lungs. (4)There are trophic fibres in connection with the vagus and also with the symphathetics.

By dividing and vagus there are found certain changes in the lungs e. g. the presence of inflammation, due to the severance of the trophic fibres. (5) There are Sensory fibres in the vagus reaching the lungs, by a section of these fibres sensibility is lost, (6) in addition to these the symphathetics furnish vasa-motor fibres arising from the spinal cord in the anterior roots of the second, third, fourth and sixth dorsal nerves passing to the sympathetics and from them to the first thoracic ganglion and then to the lungs. These represent the chief efferent fibres reaching the lungs.

Respiratory Center in Foetal Life: —In the fœtal life the fœtus receives O from and gives $CO^2$ to the maternal blood. The respiratory centre is in a condition of apnoea resulting from the large quantity of O in the blood and the absence of irritability. In the fœtal blood there is a large percentage of haemoglobin and also a large capacity for respiration. Hence normally the child in utero does not breathe. In abnormal conditions if the oxygen supply is interfered with there may be respiratory movements even when the child remains intact in the fœtal sac. If the blood were to become venous this excitation would produce respiratory action. So long as the child remains within the embryonic membrane, respiration is impossible, even if the activity of the centre of respiration be aroused, because if such respiratory movments took place then the nasal cavity would be filled with fluid.

This fluid acts as an irritant upon the afferent nerves setting up impulses which inhibit the centre of respiration. This forms the reason why after birth sometimes it is necessary to remove the mucous from the naval cavity in order to induce respiration, the musous interferfering with respiratory action. The foetal lungs have no air, although they occupy the entire space of the chest cavity along with the other organs. When inspiration commences in the new born child little air passes in at first on account of the close adhesion of the air cell walls, the expansion of the lungs, air cells and passages taking place gradually.

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# Alimentation.

Alimentation includes those processes through which matter taken into the body becomes assimilated to the tissues and the fluids. The different solid and fluid substances necessary for the body nutrition constitute food. The object of taking food is to secure the nutrition of the tissues. This food matter including the oxygen taken in in respiration passes through certain chemical changes acting as a source of energy, in time being excreted from the body in various forms as waste matter. Alimentation therefore supplies matter for the tissues and energy. In the interchange between matter introduced into the system and the system itself energy is evolved by means of which the bodily functions are performed. Thus alimentation is a process of many stages each of these stages representing actions necessary for the maintenance of the tissues and organs of

the body as a whole. These processes must be understood because from an Osteopathic standpoint lack of proper nutritive functions forms one of the main causes of abnormal or diseased conditions of the body. The tissues of the body receive their nutriment and oxygen from a fluid which circulates freely through the whole system, the blood, whose formation and the changes through which it passes represent the process of nutrition. Each of the nutritive processes may include subsidiary processes, but they are all united in the discharge of one main function, the formation of blood including its circulation and the process of blood purification.

As the body is made up of various proximate principles it is evident that the food which is to nourish the body must contain or yield similar proximate principles, The parts of the food which are digested and used by the body are called alimentary principles. These proximate principles of food are (1) water. Too little water in the system causes thirst and too much water plethora. Water may be regarded as the medium in which the various chemical tissue changes take place, The amount of water present in the system appears to influence the activity of tissue changes, for by increasing the amount of water taken in, the amount of nitrogenous waste matter excreted is increased to an extent beyond that which can be explained by the increase of fluid increasing the facilites of mere excretion. Water should be clear and free from odors. It should be fresh and palatable due to the presence of salts and carbonic acid. Spring water is rich in oxygen derived from atmospheric air and carbonic acid from the earth. These are said to exist to the extent of 10—20 c. c. of oxygen and 5—25 c. c. of carbonic acid per liter. In water there are mineral substances including carbonates, sulphates, chlorides. The hardness of water depends upon the lime and magnesia contained in it, a food water should not have more than 20° of hardness, that is 20 parts of oxide of lime to 100,000 parts of water. Water containing organic matter should not be used. (2) Salts. Mineral substances are necessary in foods, in order to promote the nutritive processes and for the purpose of nourishing the body. When the salts are absent, the health is endangered. The chief salt is chloride of sodium found in all the tissues of the body and in its fluids. In the excretions it is estimated that from 18 to 20 grains of sodium chloride are excreted daily and this small amount should be supplied daily. Potassium salts are also necessary in food. These are found in the blood corpuscles, muscle and nerve tissue while the sodium salts are found in liquids. Lime salts are also necessary for the nutrition of bony tissue. Most of these leave the body in the same form as they are introduced playing some important part in the process of nutrition and then being excreted. (3) Carbohydrates. These are starch found in potatoes, arrowroot, cereals and in the leguminous vegetables; cane sugar found in addition to the cane in some vegetables as carrots, turnips, parsnips, melons etc.; grape sugar found in fruits, honey, in wine, beer etc.: milk sugar, muscle sugar and celluose. (4) Fats. The fat in animal food consists of three substances stearin, palmitin and olein, the latter representing the fluid fat such as oils and the two

former the solid fats such as butter. If an animal is fed on fat alone the excretion of urine is less than if the animal receives no food at all. (5) Albuminous Substances. These are of two kinds, (a) animal, such as casine (milk), myosin (muscle) and albumin (egg) and (b) vegetable such as albumin in wheat and legumin in peas and beans. Albuminous matter is not found so largely in vegetables as in animals. These albuminous substances form the chief substances in the metabolism of nutrition. (6) Gases. Oxygen may be regarded as food. Its passage into the blood takes place in respiration. (7) In addition to these certain condiments and beverages are taken as food accessories. These stimulate the appetite and promote digestion if taken in moderation and under proper restraints. Alcohol although in one sense a food is not a very suitable food. It is said to be oxidized to the extent of 96 per cent, this oxidation producing heat; it also diminishes heat by interrupting the metabolism in the tissues, and lessening the oxidation of fatty substances and carbohydrates finally reducing the animal heat. Vegetable acids taken moderately act as a stimulant in salivary and gastric secretion, being changed to carbonic acid in passing through the body. The stimulant condiments, pepper, mustard etc., locally stimulate the mucous membranes and aid the flow of saliva and gastric juice, but digestion may be performed without them. Tea, coffee, coco, etc., all contain an active alkaloid along with other substances acting as a stimulant upon the nervous system, actively increasing the secretions and lessening the activity of waste of tissue. A healthy diet must (1) contain all the proximate principles found in the body or substances capable of yielding all these proximate principles. (2) include a sufficient proportion varying somewhat with the age and condition of the person, the work performed and the climate. (3) have a certain sapidity of flavor in order to promote the appetite, and assist digestion. (4) must be digestible in order to be nutritive.

DIET:—Life cannot be sustained upon one of the proximate principles or upon food yielding only one of these principles. A normal diet is a certain proportion of food of a certain composition necessary for the maintenance of life. Experience has led people to adopt certain diets and the results of their experience furnish the only means of selecting a proper food diet on a correct basis. Food includes those liquid or solid substances necessary for the nutrition of the body. In the body tissues certain processes of metabolism are necessary to sustain vitality. Chemical changes take place and certain substances are formed which are thrown off as waste matters. This daily loss takes place in connection with the lungs, the kidneys, the skin and the excrements. Food is necessary to make up for this loss estimated about 1000 grams of matter aside from the water that is thrown off. In addition energy is being expended. this energy assuming the forms of motion and heat, this energy it is estimated amounts to over 5 millions food pounds. This must be replaced by metabolism between the food and the oxygen of respiration. The food supplied to the body in the process of alimentation has therefore a most important bearing upon life, functional capacity and health.

The first law of detetics we have already referred to is that a suitable diet must provide the proximate principles of the body or what will produce these. This is equally true for plants and animals, civilized and uncivilized people. Various attempts have been made to fix an ideal diet that would meet all possible necessities of the bodily system. Moleschott taking as his basis the daily loss of an individual amounting to about 19 grams of nitrogen and 281 grams of carbon has suggested as a dietary, 120 grams of dry albuminate, 90 grams of fat and 330 grams of carbohydrates. According to the estimate this would produce normally a little over 1 million kilog. metres, yielding more than sufficient energy to sustain life. Experience has shown that dietary variations are necessary for different people according to their employments. Those actively engaged in occupation calling for muscular exertion require more food than those engaged in the lighter occupations. An ordinary diet of solid food should contain proteid 120–130 grams, fats 80–90 grams, carbohydrates 350–450 grams, salts 30 grams, representing a total of 580 to 700 grams or a little over 20–25 ozs. of solid food. In addition to this about 20–25 ozs. of water are necessary in connection with the food as ordinary food contains about one-half of its weight fluid, and from 70 to 80 ozs. in addition. The analysis of the composition of various food stuffs indicate that bread, oatmeal, peas, cheese, beef including mutton and veal, fish and eggs are rich in proteids; rice, arrowroot, potatoes are rich in fats, these being arranged so far as their own composition is concerned that deficiency in one can be made up by others. There are said to be two methods of selecting a proper diet, (1) to find out the composition of the articles made use of, estimating the amount of weight required to yield the necessary proximate principles; (2) To make a selection of food on the basis of Moleschott's estimate that 19 grams of nitrogen and 280 grams of carbon are necessary to supply the daily loss. In this case it is necessary to estimate the proportion of carbon to nitrogen in the various articles of food. In order to have an adequate measure of the vital necessities it is necessary also to estimate the dynamic value of the different food stuffs. This can be done by the calorimetric method in which an estimate may be formed of the amount of heat generated from a given weight of a certain substance or substances, taking into account the fact that complete oxidation does not take place in the system in connection with most of the substances, the amount or energy furnished being less than its estimated amount theoretically. In making such an estimate these additional circumstances must be taken account of (1) age; (2) climate; (3) the kind of employment. (1) Young persons and those growing rapidly need more food in proportion to their size than adults in order to assist the metabolism of the bodily growth. Old people need less food than middle aged and active persons and females less than males.

| | Proteids. | Fats | Carbohydrates |
|---|---|---|---|
| Children, 1 yr. | 20 | 30 | 60 |
| " 14 yrs. | 70 | 36 | 250 |
| Adult man | 100-110 | 70 | 500 |
| " woman | 80-90 | 60 | 400 |
| Old person | 70-90 | 60-70 | 300-400 |

Some think that the size of the body

to a large extent determines the amount of food necessary. In general a small body requires less food but this is subject to the same exception as in the case of the body heat, namely, that the metabolism is really greater in the smaller body, the surface being larger relatively, and therefore demanding more food relatively for that metabolism. (2) Climate. The chief element is that of temperature. When the body is exposed to a cold braeing atmosphere the body metabolism increases on account of nervous stimulation producing an increased appetite. Greater amounts of food are required in cold climates. As the metabolism of the body uses up more carbonaceous matter, the food rich in carbon elements is the most suitable. This leads to the use of large proportions of fatty substances which by the oxidation process becomes converted into heat. If the bodily system is subjected to a high temperature the metabolism is lessened although the results are less noticable in this direction than in the case of cold chiefly because the temperature of the body tends to maintain its normal heat, chiefly by an increase in the heat lost. This leads to the conclusion that more food is required in a hotter climate than in a temperate climate, chiefly fluid in character, in order to compensate for the continuous loss by perspiration. Differences in climate to a large extent however are compensated for by artificial arrangements such as clothing and the supply of heat by air as in the heating apparatus of the house. This however does not compensate wholly for the metabolic changes and hence in hot regions as compared with cold the normal diet will be maintained about the same normally except that in the hotter regions an increase in the carbohydrates and in the colder regions increase the fatty substances taken as food is required. (3) The work done by different individuals is the last element. This as we have seen modifying the amount required in the case of those engaged in lighter avocations as compared with those in active employments. One doing a hard day's manual labor requires a larger and more varied food supply than one not so active muscularly, particularly as the amount of heat liberated, the increased energy in work done being accompanied usually by an increas in the heat set free. Muscular metabolism does not necessarily require an increase in the proteid matter. In muscular labor the muscular condition and the muscular capacity at least from the standpoint of available energy must be considered. But the capacity for severe work depends upon the other organs of the body particularly the nervous system, the lungs and the heart, the nervous system being perhaps more drawn upon for energy than any other. Therefore whatever diet would be suitable for the body normally and also be of the best advantage during muscular activity increased in such proportions as to meet the general drain upon the system. In the case of mental work this is even more true, for the expenditure of energy in this case is universal, except in so far as it bears upon the loss and increased loss in the entire system. The close relation of all the parts of the body is brought out very clearly in the effect which severe mental work has as a drain upon the metabolism of alimentation. Hence the most suitable diet for brain workers is not such as would nourish and stimulate

the brain, because this would result in more or less irritation, but a diet that will keep active the juices of the body in connection with digestion and secretion.

In making a selection of foods we must (1) consider the amount of energy that may be yielded by the materials. This represents certain proteid, fat and carbohydrate substances. (2) This energy must be present in such a form as to be easily rendered available. The food must be digestible and this digestive process must be such as not to interfere with the metabolism of the system. A substance really valuable for nutrition is one that can be easily assimilated to the system. Various experiments have been made in order to discover what per centage of food used remains undigested and hence unappropriated by the system. This percentage depends of course upon the manner of cooking; on the individual capacity and to a certain extent upon the nature of the meal of which it forms a part. Rice and white bread is estimated at four per cent., meat and eggs at five per cent., Indian bread or corn at seven per cent., milk and peas at nine per cent., potatoes at eleven per cent and black bread at fifteen per cent. In addition to this the process of digestion may vary in case of different food stuffs. The same substance found in different articles of food may even in the alimentary canal pass through changes that are quite different. Proteid matter may be broken up into leucin or changed into peptone. Hence digestibility of food means not only the amount relatively taken up in the alimentary process but the nature of the changes that take place during the alimentary process. Hence the chemical composition of the food does not furnish an answer to the physiological question of its value or the value of its component elements. Food substance may be animal or vegetable. Proteids from animal and vegetable source seem to pass through the same, or almost the same changes in the alimentary process. The same may be said of the fats and extractives. Hence from a physiological stand point all that can be said as to the relative merits of vegetarian and animal diet bears upon the question of the quantity of proximate principles and the proper proportion of these principles in animal and vegetable diet. Many experiments have been made in the use of a strictly vegetarian diet. As a result it is found (1) that a much larger vegetarian diet is necessary to yield the same amount of proteid referred to as a normal diet, 20—130 grams. As yet it has not been definitely settled how much proteid matter is absolutely necessary in order to sustain life. (2) In vegetarian diet there is a marked increase of the carbohydrates and a lessening of the amount of fats. This seems to be a disadvantage to the system if kept up continously for a length of time. (3) In vegetarian diet a large proportion of diet is indigestible and hence lost to the system, being given off in the waste matter. The waste is more in amount in vegetarian than in animal diet. As excretion is one of the active functions of the body a certain amount of excretion is necessary in order to sustain, the normal function and assist the vegetable changes. But this does not seem to be compensated for in any way as a large demand is made upon the alimentary system in the form of labor and the increased volume of diet passed through

the system, lays the system open to more foreign substances which may materially effect its vitality. For these reasons vegetarian dieting would seem to be less satisfactory than the mixed dieting that includes animal food.

In the case of the human subject there is not needed any special diet for the purpose of increasing the amount of adipose tissue. The nature of the food has less effect in this case than the general characteristics of the individual organism. The same dieting in the case of two persons may produce opposite results, the one becoming fat and the other lean. The chief fat producer is the carbohydrate. In the case of animals fattened for butchering this is done by converting vegetable carbohydrate into animal fat. This process is aided by resting the system so as not to exhaust the energy of the system unless to the extent necessary for the metabolism of the body. Anti-fat treatments are more important physiologically. This may be accomplished by increasing in the normal dieting the amount of proteid and lessening the fats and carbohydrates. The reason of this is found in the fact that proteid matter increases the body metabolism, more rapidly destroying the proteid matter and the oxidation process. The Banting plan is to increase the proteid diet to such an extent as to exclude all carbohydrate substances. This is however unsatisfactory and even perilous to the functional life, because it requires such an increased activity on the part of the organism to decompose and get rid of excessive proteid that there is danger of collapse. To diminish the fats and carbohydrates at the same time increasing the amount of proteid, together with an increase in the bodily exertion, so as to set up and continue freely the metabolic processes, is the most satisfactory method. Daily exercise, even to the extent of fatigue, aided by Osteopathic treatment will materially help this by producing a very large metabolism. In body metabolism a number of conditioning circumstances are to be considered. Muscular effort increases food consumption but it is a matter of dispute what food element is affected. It has been pretty generally agreed that muscular activity does not only draw upon the proteid matter, but in some cases almost entirely upon the non-proteid substances. If the supply of food is abundant, particularly of non-proteid, that is the fats and carbohydrates, there will be no increase or at least only a very small increase in the proteid metabolism during active muscular effort. In the case of $CO_2$ it is found that a much larger amount is given off during muscular activity than during comparative rest. If it is true that there is an increase in the amount of nitrogenous matter excreted and a very large increase in the $CO_2$ discharged from the body, then the energy of muscular activity must arise from non-proteid matter. The muscle itself is a proteid substance but the changes taking place in liberating energy are largley if not wholly confined to non-proteid matter. In muscular activity there is a large composition of glycogen or the saccharine derived from it. It has been shown that a muscle subjected to fatiguing labor demands much more sugar, the power to do severe muscular work being increased by the consumption of large quanties of sugar, until the non-proteid elements are exhausted, when

the demands upon proteid matter increase. During sleep when the muscles are much less active or resting, having lost to a certain extent their normal muscular tonicity, the $CO_2$ discharged and the O absorbed are very much lessened while there is no marked change in the metabolism of proteid matter. In the case of animals deprived of food the metabolism depends upon what is found in the body consisting of stored up fat and carbohydrates, especially the sugar. The sugar is first exhausted and later the animal lives upon its own fat and proteid. It is found that in an animal feeding upon its own substance the greatest loss is in the muscle, whereas the largest consumption is in the fat which is found to be almost entirely gone after death from starvation. It was found on examination of animals that died of starvation that almost no appreciable loss had taken place in the heart, the brain and the spinal cord, although these organs were constantly active during life. They sustained their life at the expense of the other tissue substances. In the case of energy assuming the forms of heat and work done, the supply is derived from metabolism of proteid, fats and carbohydrates which become oxidized under the influence of oxygen $CO_2$ and $H_2O$ being formed and excreted, from the body. Thus the energy derived from food is determined by comparing the food taken into the body with the excretions of the body. The process of oxidation is a complex one involving the liberation of energy together with the formation of Urea, $CO_2$, $H_2O$. By the combination of the different elements of the food substances a ratio is formed representing the interchange taking place in the liberation of energy called the "isodynamic equivalent." This ratio between fats and carbohydrates is put at 1:2.3. The object of food supply is to furnish to the body sufficient proteid and non-proteid matter together with salts and water to sustain the body balance between proteid and non-proteid matter. In the case of man it is doubful if this body equilibribrium can be maintained by the use of proteids alone, so that an average diet for the human being must be composed of proteids, fats and carbohydrates. The usual ratio between proteid and non-proteid necessary for daily diet is placed at 1:5 in the solid material, apart from the necessary quantity of water found in connection with the substances used and the quantity of water necessary for the body.

In order to secure a proper diet we must consider the proportion of these substances in the different articles of diet, presupposing that these substances are digestible and that account must be taken of digestibility from the standpoint of the individual organism. In milk of an ordinary kind we find about 87 p. c. water, 3 p. c. proteid, 4 p. c. fat, 5 p. c. sugar and a small percentage of salts. including potassium phosphate, calcium phosphate with small amounts of chloride potassium and sodium chloride and iron. Cream butter yields about 87 p. c. of fat with 8 to 9 p. c. of water and .75-.80 p. c. of albuminous substance. When combined with food that yields proteid and carbohydrates it is very valuable as diet. Butter milk is deprived of the fats but contains sugar, casein and salts. Cheese contains fat and casein from 10 to 20 p. c. of the former, and from 25 to

30 p. c. of proteid. Animal meat of average leaness contains about 75 p. c. of water (fowl about 70 p. c. and pork 72 p. c.); of proteid 20 p. c. (fowl 22 p. c., pork 19 p. c.); of fat 1.5 p. c. (fowl 4 p. c., pork 6 p. c.); of carbohydrate .7 p. c (fowl 1.3 p. c. and pork .6 p. c.); the flesh of birds and fowls is richer in proteids. Raw flesh finely grated is almost wholly digested but as its value for nutrition may be counteracted by introduction into the body of foreign living bodies, endangering life as in the case of trichinosis. Meat should be cooked to a temperature varying from 56° to 70° C within the meat itself. Salted meat loses a small percentage of proteid, of the extractives and of phosphoric acid, passing into the salt brine. Eggs are found to contain much nutritious matter. There is found to be about 27 p. c. of solid and 73 p. c. of fluid, of the solid the chief constituents are albumin, vitellin, palmatin and olein to the extent of 13 p. c., cholesterin and lecithin about 11 p. c., together with about 1 p. c. of the salts of potassium and chloride, and a very small proportion of iron and sugar. As found in the egg these substances are very easily digested. When hard boiled they should be finely grated so as to come readily into contact with the gastric juice; they are more easily digested if soft boiled or raw. Vegetable foods are less easily subjected to the digestive juices, on account of the fact that the nutritious elements are bound up with cellulose and combined with large quantities of indigestible matter. The proteid in vegetables does not differ much from animal proteid. The salts in vegetables are different being chiefly those of potassium and magnesia phosphates. When the cereals are broken so as to divide the cellulose it is found the flour contains about 12 or 13 p. c. of albumen and 65 or 67 p. c. of carbohydrates, the bran being very indigestable on account of the large percentage, 30 p. c. of fibrous substances. The flour when made into bread, in the case of white bread, 11 p. c. of albumen, 1.6 p. c. of fat, 84 p. c. of carbohydrates and 1.6 p. c. of salts. Indian corn bread is rich in carbohydrates but poor in albumen; barley and oatmeal are nutritious on account of the composition of albumen and carbohydrates. Among the leguminous plants and vegetables, peas and beans are said to contain over 20 p. c. of albumen and 50 p. c. of carbohydrates, while potatoes contain 75 p. c. of water, only 2 p. c. of albumen and 20 p. c. of carbohydrates. Rice and potatoes being very deficient in proteid, require large quantities to be taken in order to be of much value in nutrition and as the proportion of carbohydrates is large, the excessive use of these is liable to produce acid ferments that interfere more or less with digestion. Along with these when used in moderation should be used some foods rich in albumen such as fish or eggs. The vegetables, cabbage, cauliflower and turnips are rich in the potassium salts and hence form a good combination diet with corned meats, which are deficient in potassium and rich in sodium salts.

Hunger is a sensation that is usually referred to the stomach but it is due rather to a general want of the system. It is usually referred to the stomach because by the supplying of the stomach with food there is a feeling of relief. It would seem to depend upon the stimula-

tion of the pnemogastrics in connection with the stomach and perhaps the alimentary canal, or the intestines. The introduction of nutriment directly into the intestines or of concentrated food substances that do not cause distension of the stomach will satisfy hunger. This would indicate that hunger arises not from the stomach alone but from other organs and tissues which demand nutrition. It is intimately connected also with the nervous system. The division of the pnemogastrics does not produce any effect upon the feeling of hunger. The use of stimulants like tobacco or alcohol lessens or at least puts off for a time its activity, possibly on account of stimulation imparted to the nerves of the stomach through the centers of the brain. The same effect may be produced by mental acts and states. Thirst may be referred to the palate and pharynx, representing a local condition of the mucous of the posterior portion of the pharynx. The section of the nerves which supply the pharynx does not diminish thirst. This condition of thirst may originate in the lessening of the quantity of water in the blood or from the stoppage of certain secretions under the influence of certain chemicals, e. g. belladonna. It is due to the general want of the tissues and can be relieved by the introduction of water into the blood vessels, or into the alimentary system. For how long a time an individual can live without food or drink is not known. This will depend upon a variety of circumstances, including bodily condition and the amount of water in bodily substance, together with the age, condition of life and the surroundings of the body. Normally entire abstinence cannot be sustained longer than 8 or 10 days although in extraordinary circumstances this period has been prolonged for 40 and even 50 days. Entire deprivaof food usually results in death after 20 days. Children and those rapidly growing succumb sooner than adult persons. With a supply of water life may be prolonged with a small quantity of food or even with no food at all, an animal surviving longer upon water than upon any other proximate principles. The entire deprivation of water usually results in death from 6 to 10 days. In some cases there is an excessive appetite this condition being termed Culimia. This is peculiarly characteristic of certain diseased conditions such as diabetes and in certain stages of fever. The minimum of food necessary to sustain life cannot be stated, becuse this depends very largely upon the individual characteristics and upon the activity of life. Even the activity of life does not depend upon the amount of food as individuals have often lived actively upon a very small relative proportion of food. It is generally stated that most persons take food in excess this being one of the common causes of gastric derangement and dyspeptic conditions. Hence the advice of hygene is to modify and regulate the diet in its quantity as well as in the proper selection of food. What is the effect of a modified diet? Deprivation of water arrests the secretions and especially the activity of the kidneys, resulting in death very soon. Hence water must be taken in sufficient quantities. The same thing is true of salts. If the albuminous matter is cut off from the food supply there is a great diminution in the excretion of urine. This becomes

more marked if the food is rich in carbohydrates. In this case the body metaabolism especially of the albuminous tissue is lessened in activity, less urine being secreted than if no food is taken at all. The carbohydrates in this case use the oxygen supply of the body in the oxidation process, leaving but little of the oxygen for the albuminous matter. These facts indicate that a mixed diet is the preferable one, being more suitable to the bodily system, the proper combination of the different foods yielding the most satisfactory results.

FERMENTATION:—Many changes during the digestive process are simply fermentations. Besides the existence, development and reproduction of ferments is intimately associated witn certain diseased conditions. In the fermentation of a fluid it becomes either clearer or more muddy throwing off gas and seething with a froth. Associated with these physical changes there are certain chemical changes represented by the alcoholic and other substances found in connection with the fluid. There is also a deposit at the bottom consisting of small organisms of a minute character. These processes were all associated together as phenomena in connection with a ferment, so called from the fact that the surface presents the frothing appearance. For a long time it was supposed that fermentation was purely a chemical process. In more recent times the question has been discussed largely from biological standpoint the ferment being caused by the presence of minute organisms. Especially through the experiments of Pasteur, who spent considerable time in the attempt to cultivate these minute organisms, we have been led back to the vital theory of fermentation according to which these represent germs of life, a peculiar form of life, as Pasteur says "fermentation is life without air," although it is admitted that these organisms assume two forms, acrobic and anacrobic, the one living through the presence and the other the absence of air. The manner in which these ferments act is unknown, although it is supposed that these minute organisms produce a kind of ferment which acts on the substance under the process of fermentation. This action is supposed to take place not directly but by reduction, in this case of course the absence of oxygen would be characteristic; if oxygen is present it is more likely that the process is one simply of oxidation. If this latter statement is true we can account for some of the results at least of oxidation taking place in the tissues. There are constant molecular changes taking place in the living tissues, these may be partly oxidation changes and where sufficient oxygen is not present these changes may result from fermentation. Aside from the fields of Bacteriology to which belong what are called the organized ferments there are the unorganized ferments or enzymes or unformed ferments that belong properly to the field of physiology. Digestion consists largely of certain processes of chemical change through which food passes in its passage through the alimentary system. These digestive changes are effected by means of these enzymes whose action is peculiar. These are substences produced inside animals and plants although not actively endowed with life. When obtained in free solution from organic matter they are colorless and tasteless, can be dis-

solved in water and percipitated by alcohol. They are like the albumen derivatives but do not contain sulphur. These are distinct from the living germs found in bacteria and are really dead although they are generated in living substances. Their chemical composition is not known although they are complex compounds Some think that these ferments belong to the albuminous derivatives. The solutions of these ferments give the proteid reactions but this may be due to impurity in the solution. These are usually classified according to their reactions.

1 Proteolytic. those changing proteids into a soluble peptone or tryphone. In connection with digestion we have the pepsin and gastric juice, the former acid and the latter alkaline.

2 Amylolytic, acting on starch and changing it to a solution of sugar or sugar and dextrine. In animal digestion we find the ptyalin of saliva, amylopein of the pancreatic juice and the liver ferment producing sugar out of glycogen.

3 Steatolytic, or fat separtive ferments acting upon the natural fats and separating them into fatty acids and glycerine by the action of the pancreatic ferment, called steapsin.

4 Inversive ferments, transforming the double into the single saccharines, e. g. converting cane sugar into dextrose, leavulose and glucose by the action of inversion of the intestinal juice and possibly to a small extent in the saliva juice.

5 Coagulating ferment or fibrin ferment of blood acting upon the proteids and producing an insoluble clot. Similar to this and of the same nature is the reunion of gastric juice which produces curdled milk. The fibrin ferment seems to belong to the class of albuminoids and has led some physiologist to suppose that all ferments belong to the same class, which, however, is not correct. These ferments are the chief agents in the food changes that take place during the process of digestion and hence form a most important element of course during digestive secretions. A ferment is a substance that causes change without itself undergoing change. This of course means that in causing a reaction the ferment is not itself used up. It does not mean that enzyme continues to exist permanently or that its action is unlimited in extent or indefinite in time. The action of the ferment is said to be on the principle of hydrolysis. This means that the ferment acts upon the separate molecular atoms, producing by contact causing these atoms to take up one or more molecules of water. The hydrated molecule is then separated so as to form smaller separate bodies. It is not known how this hydration takes place. Some physiologists have supposed that it was accomplished by catalysis or by the influence of contact arising from the presence of the enzyme. In addition to this it is said by others that the presence of the ferment causes vibrations in the substance among its molecules, these leading to the absorption of fluid and breaking up into smaller bodies. Others have said that the ferment produces a chemical reaction without undergoing any change in itself, acting the part simply of a medium in conveying to the substance of the chemical influences. This is not unknown in the fields of chemistry as we find it in connection with the blood, the haemoglobin becoming oxy-

haemoglobin and after delivering the oxygen to the tissues returning to its original form. The presence of these ferments in the human body in connection with the juices explain largely the different processes of digestion.

DIGESTION:—Digestion includes all those processes and changes through which the food passes in the alimentary canal for preparing it for entering into the blood by the process of absorption. These changes are the result of several processes to which the food is subjected in its passage through the mouth the stomach and the intestines. These processes to which the food is subjected are various; in the mouth there are two, mastication and insalivation. The food is introduced into the mouth by the hands or some other artificial means devised for the assistance of the hands. After the introduction of the food into the mouth it is subjected to the process of decomposition accomplished by the movements of the jaw and teeth and later is mixed with a certain fluid secretion.

MASTICATION:—Mastication is the division of the food and its breaking up by the teeth. The food is cut by the sharp edges of the incisors and cannes and ground between the rough surfaces of the bicuspids and molars. The former result is produced by the alternate downward and upward movements of the jaw. The diagastric muscle aided by the mylo-hyoid and omo-hyoid muscles open the mouth, the temporal, masseter and internal pterygoid closing it. The external pterygoids act in alternation on the two sides producing the horizontal action of the under jaw. The orbicularis oris keeps the mouth closed. The trituration of the food between the molars is caused by a kind of rotary action of the lower jaw due to the movements alternately of the external pterygoids. The food is rolled about by the tongue which pushes it about between the teeth while the contraction of the buccinator muscles prevents the accumulation of the food between the cheeks and the dental arches. The process of mastication is assisted by the mixture of the food with the fluids. If the mastication is complete the food is ready for digestive actions. Complete mastication is very essential in order to prevent deragements of the digestive systems. The sensory impressions relative to the position, state and readiness of the food for swallowing are carried to the brain, chiefly by afferent fibres of the fifth pair of cranial nerves, and the glosso-pharyngeal in connection with the tongue. Motor influences are conveyed to the muscles concerned in mastication by the following nerves: The motor fibres of the fifth through its inferior maxillary branch to the buccinator, the anterior belly of the diagastric and the masticatory muscles, the hypoglossal regulates the tongue, furnishing by the descendens noni impulses to the omo-hyoid, sterno-hyoid and sterno-thyroid. and by hypoglossal branches to the genio-hyoid and thyro-hyoid. The facial motors supply the posterior belly of the digastric, the lip muscles and the buccinator. The reflex centre is in the medulla. In salivation during mastication, the food is mixed with the fluid saliva, a fluid secreted by the parotid, sub-maxillary and sub-lingual glands and by the small glands of the buccal mucous membane. The saliva is a thickish transparent glairy and somewhat turbid fluid with a slight

sediment. In the sediments are found flat epithelium cells from the mucous membrane of the mouth, mucous corpuscles and spheroidal cells from the salivary glands known as salivary corpuscles. Its specific gravity averages about 1005 to 1009. The saliva is alkaline in reaction, due to the presence of alkaline sodium phosphate, its alkalinity being about .08 p. c. It consists of water with about 5 p. c. of solid matter. The solids consist of salts including lime carbonate, alkaline chlorides and the phosphates of lime and magnesia; small quantities of mucin and albumen and unorganized ferment or enzyme ptyaline, which has the power of converting starch into various forms of sugar, dextrine and maltose. This effect is produced more quickly if the starch is boiled, as boiling removes the cellulose envelopes of the starch granules. There are other conditions favoring the ferment power of ptyaline, including a moderate temperature 70 ° F., and the fluid in which the action is taking place being either alkaline or neutral. The various salivary secretions have been secured by the use of tubes in connection with the glands. The parotid saliva is clear and limpid, not viscid, it is slightly alkaline and yields but little ptyaline and traces of urea. Under exposure to air it deposits lime carbonate. The sub-maxillary saliva is viscid on account of the mucin. It is more alkaline and contains ptyaline. The sub-lingual gland secretion is still more viscid on account of the large proportion of mucin aad is very marked by alkaline. In young children the saliva contains very little ptyaline, the ferment appearing a few months after birth, after which salival secretion increases in connection with the dentition process. The function of the saliva is three-fold, (1), to convert starch into sugar, glucose and maltose, (2) to moisten and soften the food and to assist in swallowing; and (3) to keep the mouth moist and so facilitate articulation. This saliva supply simply acts upon one substance, starch. The conversion takes place freely at 35 ° C., but if the temperature is lower the conversion is hindered as is also the case if it rises above 60 ° C., being entirely arrested at 70 ° C. The effect of heat seems to be in the ferment rather than in the starch substance. Saliva acts most freely in a neutral solution, excessive acidity arresting its activity, weak acidity or alkalinity diminishing activity. The activity is most marked if the saliva is diluted with the digestive substance in the ratio of 1:100. If the dilution is largely increased a small quantity of sugar is still converted. Very small quantities of acid proteids will hinder and large quantities will destroy the activity of ptyaline. Hence the formation of these acid proteids retards the action of ptyaline until it ceases to act at all. Human saliva is not very active, its activity being directed to the moistening of food for swallowing. The amount secreted by man every day is estimated at from 500 to 800 grams. The secretion depends upon the nature of the food. In the case of dry food where only a small quantity of water is used the secretion is large. The secretion is also increased by speaking and by the sapidity of the food. The ordinary flow of saliva is a reflex action. The food substance stimulates the glosso-pharyngeal and the lingual nerves which convey impressions to a center in the medulla from efferent impressions pass to the salivary glands.

The efferent nerve to the sub-maxillary gland being the chorda tympani. The influence of the nervous system on salivary secretion has been chiefly studied in connection with the sub-maxillary gland There are connected with this gland in man fibers from the facial through the chorda tympani and from the sympathetic. The chorda tympani springs from facial nerve at the extremity of the Fallopian aqueduct, passing through a small canal opening on the posterior wall of the tympanum, passing across the tympanum and then passing out of this canal by an opening on the interior extremity of the Gasserian fissure, it passes down along the internal surface of the internal ligament, connecting with the lingual trunk, the sub-maxillary ganglion and the blood vessels in connection with the tongue. This sub-maxillary ganglion is closely related to the lingual branch of the 5th nerve by anterior and posterior roots, the latter carrying the fibers from the ganglion to the chorda tympani. The sympathetic also sends out fibers to join this ganglion arising from the plexus of the facial artery. The blood vessels of the sub-maxillary glands are connected with the ganglion by means of a number of nerves, several passing to the mucous membrane of the mouth. If a tube is applied to the sub-maxillary gland a whitish fluid passes out. If chemical stimulation is applied to the tongue changes may be made in these secretions, a weak solution of acid producing a clear fluid and and an alkali solution a viscous fluid.

These changes are due to nervous stimulation, depending upon the nerve to which stimulus is applied.

1. Stimulation of the sympathetic produces contraction of the arteries, a slowing of the circulation, the blood passing from the gland being of deep, dark color. The secretion is diminished, the saliva becoming thready and viscid and contains numerous corpuscles and protoplasmic lumps together with mucin. If the stimulation be long continued the saliva becomes limpid, very like the chorda secretion, indicating that the chorda and sympathetic secretions are similar in their natures. Previous to the effect produced upon the secretion after the application of the stimulus there is a brief period before the changes take place in the saliva. The fibres are vaso-constrictor and probably act by stimulation of the local ganglia.

2. Stimulation of the chora tympani after its division causes dilation of the arteries, a quickening of the circulation, bright arterial blood passing into the veins, copious watery secretion with free salivary corpuscles and protoplasmic masses and salts. Thus the chorda is vaso-dilator and increases the secretions. The fibres are so far as the vessels are concerned vaso-dilators, but it is believed that some are also distributed to the secreting cells of the gland for if atropin be administered the stimulation of the chorda tympani will still cause the dilation of the blood vessels but no secretion of saliva. In this case the atropin paralyzes the secretory gland but not muscular fibres of the chorda tympani. The nerve fibres in all probability dilate the blood vesseles by inhibition of the local ganglion.

3. If the lingual nerve be cut and stimulation be applied to the central end, the secretion increases very much. This secretion will not increase, if before

stimulation the chorda tympani be cut also. From this we conclude that there is a nerve circle including sensory fibres from the lingual, a center in the brain and fibres in the chorda producing secretions by reflex action. If the sympathetic, the chorda and the lingual all be cut and stimulation be applied to the mucous lining of the mouth, the secretion increases, indicating that the sub-maxillary secretion is limpid: and the chorda activity is excited by stimulus applied to the lingual and glosso-pharyngeal nerves or the sensory fibres of the fifth in the mouth and tongue or the olfactory branches or the vagi branches in the stomach, all of these producing a watery secretion. The secretory center is in the medulla, close to the 7th and 9th cranials. This center may be stimulated not only by afferent impulses from below but also by impulses arising in the cerebrum, arising from a psychic influence connected with the thought of a savory meal. This influence may be either accretion or inhibitory, in the former case producing a free watery secretion in the mouth and in the latter parching the mouth. Secretion in the sub-maxillary gland is not a process of filtration but takes place internally in the gland determining the blood flow to the gland. Secretion is not arrested by the pressure becoming greater in the gland than in the arteries. Even after decapitation the secretions will continue in the gland, indicating that the saliva is not simply filtered through the gland from the blood but is produced in the gland cells. In confirmation of this it is claimed by some that the nerve terminals are found in the gland cells, at least they seem to be intimately connected. During the secretory process the gland temperature is raised from 1 p. c. to 2 p. c. producing an increase in the venous blood leaving the gland as compared with the arterial blood received into it The changes in the gland also produces certain electric influences, a change taking place between the normal gland and the gland under stimulation, resulting in a negative variation.

Secretion is thus dependent upon three factors (1) blood supply; (2) nervous impulses; (3) the activity of the gland corpuscles. This means that it is not due simply to blood pressure. This is shown by the fact already referred to in reference to the stimulation of the fibers of the chorda tympani in connection with the sub-maxillary gland when the system is under the influence of atropine. It can also be shown by ligaturing the duct of the gland when secretion will still continue although the pressure inside the gland is greater than that inside the blood vessels. The sub-maxillary ganglion appears to be a kind of secondary reflex center for the sub-maxillary gland. If the nerves that connect the tongue with the central nervous system be divided substances applied to the surface of the tongue cause a flow of saliva.

MASTICATION:—Mastication is a voluntary act under the direction of the muscular sense and the sensations. It is not however purely voluntary, as the paralysis of the nerves controlling the tongue takes away the influence of sensations which aid so materially the voluntary act.

DEGLUTITION:—After the process of mastication is complete by breaking up the food and mixing it thoroughly with saliva, it is formed into a circular bolus

and conveyed to the stomach by the process of deglutition, which consists of a succession of complex muscular movements. This transmission takes place through the pharynx and œsophagus. It includes the passage of the food from the mouth to the stomach. It may be divided into three stages.

1. The voluntary stage during which the bolus is by the movements of the tongue carried back to the fauces. As soon as it passes within these there commences and is rapidly completed the (2) stage, spasmodic stage. The tongue is jerked upward and backward by the stylo-glossi muscles and thus the bolus is thrown into the lower part of the pharynx. At the same time other movements take place by which the openings leading from the pharynx, except that into the œsophagus, are closed and in this way the bolus is prevented from entering them. Various steps in this process are noticeable, (a) the palato-glossi muscles contract and produce a narrowing of the anterior arch of the fauces preventing the bolus from returning to the buccal cavity. Having entered the pharynx, certain movements are necessary in order to prevent its passage into the nasal cavity or trachea and to carry it into the œsophegus; (b) the soft palate is raised by the levator palati muscles, which by the contraction of the palato-pharyngeal muscles the two posterior pillars of the fauces are made to approach one another like the blades of a pair of scissors, having between them a narrow passage that is filled up by the uvula. In this way there is formed a sloping shelf which cuts off the bolus from the posterior nares and the eustachian tubes. It is a matter of dispute whether the orifices of the eustachian tubes are open or closed during degultition. The posterior part of the soft palate, I think, is directed back toward the wall of the pharynx, occupying a horizontal position and almost closing the eustachian tubes. The mylo-hyoid muscles contract rapidly thus lessening considerably the buccal cavity, the bolus being quickly sent from the mouth through the pharynx and œsophagus into the stomach, the contraction taking place in the œsophagus and pharyngeal walls being supplementary, to drive down any remnants of the bolus; (c) as the tongue is jerked upwards and backwards the hyoid bone with the pharynx and larynx is carried upward and forward. Hence the base of the tongue presses the epiglottis down over the superior aperature of the larynx. The closure is completed by the constriction of the muscular fibres connected with the epiglottis. At the same time the rima glottis is closed the arytenoid cartillages and true vocal cords being brought close together, the cushion of the epiglottis fits in between the cords. By these means the orifices leading from the pharynx are closed with the exception of that into the œsophagus. The œsophagus and lower part of the pharynx are somewhat raised to meet the descending bolus by the contraction of the stylo-pharynges and palato-pharynges muscles.

3. The involuntary stage. The constrictors of the pharynx close over the food which enters the œsophagus along which it is carried by the peristaltic constriction. When the food enters the œsophagus the pharynx falls downwards, the openings of the mouth, nasal cavity and glottis being opened and the frag-

ments of food being carried downward by a succession of œsophageal contractions. The œsophageal movements are undulatory and hence they are called peristaltic. The circular contraction originating in the pharynx passes into the œsopagus being first communicated to the transverse coat of the œsophagus and then assisted by the contraction of the longitudinal coats the movement being always directed downwards. These peristaltic movements may be carried out by the muscles without any assistance from the nerve fibres terminating in the muscles and apart from the central nervous system, as these can be seen in the organs when removed from the body. But in the living body the connections are so close with the nervous system as to make the connection of nerve and muscle inseparable in the production of peristaltic action. These movements of the œsophageal walls are very much like those found in the stomach and the intestines. The muscular coating of the alimentary canal consists of two layers, an external thin layer arranged longitudinally and an internal thick layer arranged transversely, with a layer of connective tissue in the middle. When constriction takes place in the transverse layer the contraction is transmitted downward causing contractions of the circular layers. This causes the constriction of the tube pushing forward the contents. In the case of the longitudinal layer a contraction of any portion of the tube helps forward the contents by drawing the tube over the contents immediately above. These contraction movements are transmitted all along the walls of the tube. The transverse and longitudinal contractions are supposed to take place at different times and not simultaneously, because simultaneous contractions would tend to neutralize each other. It is supposed that longitudinal contraction accompanies transverse relaxation and vice versa, the thick coat of the transverse representing the stronger force, the thinner longitudinal coat assisting the movements forward. These conjoint movements produce a writhing and twisting in the walls and along the tubes of the intestines which is called peristaltic action. All movements in deglutition are induced if not produced by the stimulation arising from food or liquid coming in contact with the tongue and the fauces. These movements are aided by insalivation of the food and the closure of the mouth, as it is very difficult to swallow dry substances and with the mouth open.

Nervous Arrangement of Deglutition:—Deglutition as a whole represents a reflex action. It is impossible without some stimulation of the mucous of the fauces. The first stage represents a voluntary action. The second stage is said to be partially voluntary and partially reflex. The movements however may take place involuntarily and during unconsciousness. In the last stage it is surely involuntary, the will having nothing to do with the action and movements concerned. It is a complicated reflex action therefore, involving many muscles, these muscles co-operating to produce definite results, the connections and the results being very definite. The nerves associated with the acts of deglutition are:

1. Afferent sensory nerves carrying impulses to the centers, the glosso-pharyngeal in connection with the tongue

and pharynx, the branches of the 5th pair of cranial nerves from the palate and tongue, and the pharyngeal branches of of the superior laryngeal portion of the pneumogastric from the upper laryngeal orifice.

2. The center of reflex action lies in the medulla oblongata and the Pons varolii. If an animal's brain be removed leaving the medulla, deglutition can be induced by stimulating the fauces. If the medulla be removed deglutition is impossible. Various centers have been localized in the nucleus of the 7th, the pneumogastric and the glosso-pharyngeal, the 5th and hypo-glossal, all of these being closely grouped together.

3. The efferent motor nerves carrying impulses to the muscles of deglutition are the hypo-glossal to the thyro-hyoid, genio-hyoid, hyo- and stylo-glossal muscles of the tongue and the glosso pharyngeal, the pharyngeal plexus formed from the pharyngeal branch of the pneumogastric and the sympathetic to the constrictor muscles of fauces and pharynx; the 5th pair of nerves to the anterior belly of the digastric and the mylo-hyoid muscles; the 7th (facial) to the posterior belly of the digastric and the stylo-hyoid muscles; the glosso pharyngeal muscle and the laryngeal branches of the vagus to the laryngeal muscles.

Digestive Processes that take place in the Stomach:—When the food reaches the stomach it is subjected to the following influences: (1) a temperature of about 104° F; (2) certain movements and compression; (3) the action of the gastric juice; (4) Absorption also takes place in the stomach.

The Movements:—Stomachic movements have two objects;

1. In order to subject the stomach contents to the influence of the gastric juice.

2. To throw the food when partially digested into the first portion of the small intestines. Hence a distinction has been drawn between two stages in the movements called churning and propelling movements. When the stomach is empty it is curved from above downwards. When food reaches the stomach and it is filled the stomach rotates on its long axis so that the greatest curvature is carried forward, the anterior surface is carried upwards and the posterior surface downwards. The muscular fibres of the stomach contract on the food and cause it to circulate, the current passing from the cardiac orifice along the great curvature and back again by the lesser curvature, while at the same time other currents carry the food which is in contact with the mucous membrane to the deeper parts of the stomach and vice versa. This gives rise to rotary movements of the contents of the stomach, the rotations taking place successivsly at short intervals and lasting for a few minutes. The contact of the food with the mucous membrane of the stomach produces a stimulation which is strengthened by the chemical action of the gastric juice. These movements result in the complete mixing of the food with the fluids. In this way the food is thoroughly churned and its complete admixture with the gastric juice is secured. The contraction of the gastric muscular fibres is at first slight but becomes increasingly active as digestion proceeds, that is as the stomach gradually empties. From time to time the pyloric sphincter relaxes and portions of food pass into the small intestine (duo-

denum.) This movement is sudden, being actively marked at the pylorus. These movements take place at intervals of 15 minutes until all the food is digested and emptied into the small intestine. The nervous mechanism of the stomach is supplied by the pneumogastric and the splanchnic nerves. If the sympathetic is stimulated there does not result any movements. If on the other hand the pneumogastric is stimulated active movements occur in the cardiac portion, posteriorly, if the stomach is dilated. If the sympathetic and pneumogastric be divided these movements are not suspended, indicating that the ganglia act as centers of activity, even after separation of the central nervous system. If the splanchnic are stimulated these contractions cease. Thus the movements of the stomach walls are due to local influences arising from ganglionic centers. Impulses conveyed along the pneumogastrics excite these movements or cause these movements to become more vigorous whereas impulses conveyed along the splanchnic sympathetics exercise an inhibitory force. If the stomach wall be subjected to a shock either produced by striking with a flat instrument or the application of induction shocks there will arise certain contractile movements being transmitted along the abdominal walls. Vomiting is intimately connected with these digestive movements. The act of vomiting is due to the direct or indirect stimulation of a centre situated in the medulla. It may be produced:

1. By the stimulation of the afferent nerves of the gastric mucous membrane, for example, the introduction into the stomach of some irritant, such as mustard, sulphate of copper, bile, undigested food, these substances either acting directly upon the mucous of the stomach or after absorption into the blood by influencing the reflex centers.

2. By substances introduced into the blood and acting upon it or else absorbed into the blood through the skin, e. g., the injection of tartar emetic into the blood.

3. Irritations of other organs affecting the stomach reflexly, e. g., tumors, certain conditions of pregnancy, gall stones.

4. Impressions reaching this center from higher centers, depending upon psychic impulses, e. g., arising from feelings, emotions, taste, odors. Sea sickness arises not from the food in the stomach but from a disturbance of the feeling of equilibrium in the bodily system, particularly of the stomach.

5. Vomiting arising from the reflex action produced by inflamation, e. g., in acute meningitis. From the center in the medulla, when it is stimulated, a series of complicated efferent impulses pass, some of these traveling along the vagi and causing contraction of the walls of the stomach and of the abdominal muscles.

There are several characteristic stages of vomiting;

1. Nausea. Vomiting is usually produced by a nauseous feeling accompanied by a salival flow and the swallowing of some air.

2. Accompaning this is a deep inspiration by which the diaphragm is pushed down, the lungs being full the diaphragm forming a solid base against which the stomach can be compresssed. Sometimes this compression causes the ejection

of a quantity of gas. Associated with this is sometimes a retching accompanied with a deep inspiration.

3. Immediately there after the fibres of the diaphragm contract longitudinally and are shortened; the opening of the cardiac orifice, which is close under the diaphragm, takes place in connection with the inhibition of the sphincter and the constriction of those fibres ranging from the œsophagus to the stomach.

4. The abdominal muscles and the gastric walls contract, the contents of the stomach being forced into the œsophagus along which they are carried into the pharynx by anti-peristaltic action and ejected through the mouth, the opening into the larynx and nasal cavity being closed as in deglutition, although they sometimes remain open and matters are forced out the nasal openings. There are two marked actions in vomiting, (1) the distension of the cardiac opening and (2) the compression of the walls of the abdomen; both of these being necessary in order that the action may be effected. Sometimes the former takes place as in poisoning by curare in which case there is simply an internal stomach pressure resulting in the emission of gas. What is commonly called water brash or heart burn is probably due to this internal movement of the abdomen. Eructation or wind consists of a sudden forcing of gas out of the stomach producing a sound which is very characteristic in the upper portion of the œsophagus. The nervous arrangements of vomiting are obscure. The center is in the medulla. There is really no special center. Efferent impulses causing the deep expiration must come from the respiratory center. The distention of the cardiac opening is produced by stimulation passing along the pneumogastrics because if these are divided vomiting is prevented or rendered almost impossible through lack of dilatation of the orifice. The internal stomachic movements and the movements of the œsophagus are carried out under the influence of the glosso pharyngeal and sympathetics. The salival flow in connection with the nausea arises from impulses passing along the chorda tympani. These various mechanisms are brought into activity by the stimulation of different centers, impulses being passed from one center to another thus interfering with the rhythm of the movements in the stomach Vomiting is a reflex action, the impulses usually passing along the splanchic and pneumogastric nerves. This does not prevent however, direct action upon the centers as in abnormal condition, of the medulla resulting in cerebral vomiting and in some cases of poisoning as well as under the influences arising from the higher centers that depend upon emotions.

THE GASTRIC JUICE:—The gastric is juice easily obtainable for experimental purposes but it is difficult to determine the normal characteristics of the fluid in the stomach. Investigations have been made in connection with the production of artificial gastric juice. These however only represent in a general way the gastric juice as normally it is complicated by admixture with food, fluids, etc. When it is secured in purity it is a clear, colorless fluid with a sour odor and taste, the reaction being distinctly acid arising from hydrochloric acid to the extent of about 2 p. c. Its specific gravity in the human subject is 1001 to 1003. On microscopic examinaton it

does not present any well marked characteristics. In the human gastric juice the amount of solid matter is very small about .05, of this solid matter the greater proportion is found to be salts especially the chlorides and small traces of iron. There is always a free acid, hydrochloric acid together with lactic acid and acids which are secondary the result as a rule of fermentation changes in the food. There is a small quantity of albumen and ferment pepsin which can be extracted from the gastric mucous membrane by glycerine and which when dried appears as a grayish white powder, soluable slightly in water. This pepsin in combination with hydrochloric acid has the power of converting ordinary proteids into peptone which differ from ordinary proteids as follow:

1. Their solutions are not coagulated by heat or alcohol.

2. They have the power of passing with considerable ease through animal membranes.

3. They are easily dissolved in water.

4. Mineral acids, acetic acid and such other acids do not precipitate the solution.

5. Such acids as tannic acid, corrosive sublimate do not cause precipitation. Besides pepsin the gastric juice contains another ferment, which as it has the power of curdling milk may be called rennin ferment. The gastric juice freely dissolves coagulated proteids which seem to be almost insoluable. There are supposed to be several kinds of peptones in connection with the gastric juice. These all differ from albumose in the fact that peptone is diffusable whereas albumose is not and peptone can not be precipitated by sulphate ammonium like albumose. The gastric juice changes the less soluble proteid into soluble form being either converted into peptone which is the most soluble of the proteids or else being left in the less soluble form of parapetone. This conversion of proteids into peptones is facilitated (1) by a medium temperature from 35 to 40 degrees C. (2) by certain movements such as we find in connection with the stomach, constant movement favoring digestion. The presence of acid below or beyond the normal percentage, 2 per cent of hydrochloric acid, the making of the juices alkaline, a temperature below 50 degrees C or above 60 degrees C and the presence of concentrated digestive products retards or arrests the changes in connection with the gastric juice. The blood is conveyed to the fundus and pyloric glands the fluid being poured from the capillaries so as to suffuse the membrane, the plasmic fluid being secreted in the cells of the glands as the elements out of which the juice is formed. In the glands of the pylorus the pepsin is formed. When the stomach is inactive the marginal glandular cells decrease in number; when food is introduced into the stomach the principal cells decrease, producing large numbers of marginal cells in which the hydrochloric acid is formed, whereas the pepsin is found secreted in the principal cells in connection with the fundus and pyloric glands. The hydrochloric acid is formed out of the blood. It is supposed that lactic acid is first formed by means of a ferment, the acid setting free chlorine from the sodium chloride, the chlorine being combined with hydrogen to form hydrochloric acid, others suppose it due to certain currents passing through the mucous membrane producing re-

action in the carbonate of soda and the sodium chloride of the blood. A more probable explanation is that it arises in the molecular dissolution of the chlorides accomplished by the protoplasmic action. The liberated base in this case is excreted by means of the kidneys. In the principal cells there is found certain matter which under the influence of hydrochloric acid produces pepsin, the albumin being converted into peptones. Thus the matter inside the cells contains substances which can produce pepsin and hence this internal substance is called pepsinogen. This pepsinogen is supposed to be in union with a proteid and that the union is broken up by the use of acid. The pepsin found in the gastric juice varies according to the stage of the digestive process, being smaller about the second hour and greatest about the fifth hour. There is no pepsin found in the mucous of the fœtal stomach during fœtal life, although it is said that just before birth the stomach assumes digestive powers. The gastric juice in digestion seems to act as a ferment, this ferment being the pepsin. It is not itself a proteid. It differs from ptyalin the salival ferment in this—that pepsin has a close affinity for acid whereas ptyalin is most active in a neutral solution, in the case of pepsin united with hydochloric acid we have the compound peptohydrochloric. The amount of pepsin in the gastric fluid varies from .2 to 1.5 per cent. If the mucous membrane is divided into small pieces and steeped in alcohol for a day, then removed from the alcohol and put in a strong glycerine solution in which it is allowed to remain from 10 to 21 days. This gives us the glycerine extract of the mucous membrane which is found to be very peptic. The gastric juice on analysis yields in 1000 parts according to Schmidt 995.4 parts of water, 3.19 pepsin and other organic matter, 1.46 sod. chloride, .55 Potassium chloride, .06 calcium chloride, .20 acid and 12 phosphates of lime, magnesia and iron. In addition to the pepsin there is also usually present the rennin ferment and the lactic acid ferment which converts sugar into lactic acid. Syntonin is formed during the first part of the process. By the use of alkali this may be precipitated a part of the proteid substance being left in the neutral fluid, this substance being peptone. In additon there is formed the parapetone, an albuminous substance, soluble in water and that may be precipitated by nitric acid. In the first stages of the digestive processes a large proportion of the parapetone is found and a small quantity of peptone. As the digestive process goes on the peptone increases and the parapeptone decreases until at the close of the digestive process very small traces of the parapetone are left. In the process of digestion a number of intermediate substances are formed called by Halliburton proteoses, these different substances representing the different stages in the development of peptones. The peptones are albuminous. It is supposed that they are formed by hydration, an atom of albumin being united with a drop of water. This is proved by introducing acetic acid into the peptone and thus dehydrating the molecules by removing the water and thus converting the peptone into albumin.

The digestive process is influenced,

1. By the gastric secretion which goes on during the entire digestive process, the food being mixed with fluid in con-

nection with the pepsin and hydrchloric acid so as to produce the proper admixture and dilution of the food.

2. When the peptones are formed during digestion they are absorbed into the blood through the blood vessels, together with water and the soluble substances found in the water, the remnants being passed into the small intestines.

3. The stomachic movements facilitate digestion by introducing the food contents into the different parts of the mucous membrane of the stomach and thus bringing them into contact with the gastric juice. When the stomach is empty its mucous membrane is of a pale grayish color and covered with a thin layer of mucous. The introduction of any substance more especially food leads very promptly to the dilatation of the blood vessels of the mucous membrane which consequently becomes red in color and copious in the secretion of gastric juice. Gastric secretion may be produced by the feelings or emotions through connection with the higher centers in the brain. The dilatation of the blood vessels and the consequent secretion of the gastric juice is a reflex action similar to that which produces the flow of saliva. If the vagi are divided during the digestve process the mucous becomes pale, the stimulation applied to the central end of the divided nerve producing the dilatation of the vessels in the membrane. Afferent impulses therefore pass from the gastric mucous membrane along the vagi to a center in the medulla inhibiting the action of the vaso-motor center governing that region, resulting in diminished nervous impulse to the stomach blood vessels producing dilatation. Efferent impulses pass along the fibres of the sympathetic to the ganglia in the walls of the stomach, these ganglia exerting a local influence upon the calibre of the blood vessels and perhaps also the activity of the corpuscles in the gastric juice. By the general influences of temperature the stomach movements and the direct action of the gastric juice, the food contents become so changed as to be prepared for absorption.

The result of these influences on the food is to form a semi-fluid heterogeneous mass, the chyme. This has an acid reaction with an acid odor and differs in color according to the character of the food. It consists of water, salts, sugar converted out of the starch by the salival action; the remnants are left over from the salival process; fatty substances which have been dissociated from the food or liberated from the animal cells; albumen in the various stages of development into the peptones; and the undigestible matters left over after the action of the digestive juice. There are two stages in the digestive process in conection with the gastric juice

1 A short period during which the saliva acts upon the starch found in the stomach in fermentation.

2. A longer period during which the peptones are developed under the action of the gastric juice. The first stage depends upon the acidity of the juice. If the juice becomes acid to the extent of 5 p. c. then the salival fermentation ceases. The acidity of the gastric juice retards butyric fermentation, lessening the amount of hydrogen in the stomach. There is found in the stomach always certain quantities of gas either from the air taken in with the food or from the intestinal organs. The oxygen of the

air taken by deglutition becomes quickly absorbed so that in the stomach the gas is deficient in oxygen and rich in $CO_2$. The gastric juice acts differently upon the different food substances. Milk becomes rapidly coagulated, the saccharine and salt substances found in solution being absorbed, the fatty substance being freed from the milk cells and the caesin changed into peptone. The coagulation of milk is produced by the rennin ferment, this ferment being easily destroyed by alkiline solutions. In the case of animal muscle, the dissolution takes place in the connective tissue between the fibres, exposing the transverse striae. In this way the fibres are broken into pieces and thus dilsolved into their elementary sabstances. The ligamentous, tendionous and cartilaginous tissues dissolve more slowly. After being cooked they are acted upon very much like gelatine. The gastric juice does not effect the (horny) tissues, such as hair, nails, skin. The elastic tissues may be dissolved under lengthened digestion yielding an elastic peptone. The red corpuscles become disunited, the haemoglobin being separated into haematin and globin under the influence of the gastric juice, the globins being transformed into peptone Bones are not dissolved but the acid of the gastric juice extracts some of the salts leaving the bone in a honeycombed condition. Vegetables in their natural condition are indigestible because of the enclosure of the substances within a cellulose covering, the cellulose being unchanged by the gastric juice. After being cooked the cellulose yields liberating the nutritive elements such as starch, sugar, etc., setting them free to the action of the gastric juice. Some of the salts are dissolved in the juice, the dissolution yielding carbonic acid in the case of the carbonates.

Experiments have been made to test the rapidity of the digestive process. In artificial digestion the process is much slower than normally in the stomach. The rate of digestive action depends upon the food, its nature, and also upon the division that takes place in the food, so that if the division is increased so as to increase the superficial area of the food with which the juice comes in contact, the process is assisted. Fluids are quickly absorbed, the solids contained in the fluids being concentrated before coming in contact with the gastrict juice. The solid substances of food are normally very quickly subjected to digestion. It is estimated that within thirty minutes after a meal is taken, the food is changed into chyme, the stomach being emptied within two or three hours. Various experiments have been made to discover foods easily digested. Beaumont found that tripe and rice digested in one hour; eggs, apples, trout, salmon and venison in one and one-half hours; milk, barley, liver, fish and tapioca in two hours; lamb, pork and turkey in two and one-half hours; mutton, fowl and beef in three to three and one-half hours, and veal in four hours. This does not indicate the nutritive value of the foods, because rapid digestion does not always indicate that the food is nutritious. In the case of a dog fed upon animal food, it has been found that digestion begins immediately, continues active during the first two hours, then gradually diminishes in activity until the twelfth hour, when the digestive action is completed.

The question is asked in physiology, why does the stomach not digest itself?

The stomach of another animal will be readily digested. If the animal is killed the stomach itself may be subjected, at least partially, to digestion if normal body heat is kept up. Even in the living subject, if the circulation is cut off from a portion of the stomach as in the case of intravascular blood clotting or ligaturing the blood vessels, the gastric juice will attack the stomach itself, resulting sometimes in perforation of the stomach. Some have suggested that the vital principle protects all the living organs, such as the stomach and small intestine from the action of their own secretions. This does not explain, however, the protection, for it has been shown that the leg of a living frog may be introduced into the stomach through a fistula without severing its connection with the living body, in which case the digestive process will go on. Others have suggested that the epithelial lining of the stomach protects it or that the blood, alkaline in its nature, freely circulating in the organ, neutralized the acidity of the juice preventing the digestion of the stomach. The stoppage of the blood flow withdraws this element and permits of the action of the secretion upon the stomach. In case where death is sudden, post mortem examination evidences the partial digestive action in the corrosion of a portion of the lining of the stomach, this corrosion even extending to the proximate organs such as the diaphragm and liver. This view does not explain the protection afforded to the intestines against the action of the pancreatic juice. The immunity probably arises from the living properties of the organ, the stomach and intestine, these organs being arranged so structurally as to be capable of resisting in normal conditions the digestive action of its own secretion.

What are the conditions that favor digestion? Aside from individual characteristics which play an important part in digestion of food, digestion depends upon:

1. The amount of food taken. In order to promote digestion the stomach needs to be normally dilated, this of course implying a moderate supply of food.

2. Sufficient time should elapse between meals so as to permit the food to be completely digested before new food is introduced into the stomach.

3, Sufficient exercise both before and after eating assists digestion. This means moderate exercise. Violent exercise being dangerous and against digestion.

4. The psychic conditions also influence digestion. Disturbed mental conditions interfere considerably with digestion. Mental equilibrium therefore is a favorable condition.

5. Physical health is also a necessary condition of proper digestion.

6 Age and changes in life affect digestion. Digestion is more active in the young. The changes of life, whether in regard to changes of avocation, temperature or the normal changes in life influence digestion. The stomach's function normally is to act upon the food by chemical and physical processes so as to prepare the food for the later digestive stages in the intestine. The stomach has concentrated the food substances into a semi-fluid substance, representing partially digested as well as the undigested matters to be more completely digested in the intestines. Gastric digestion is

preparatory to pancreatic digestion under the influence of tripsin. According to this the human being can live without a stomach. We have to give up the idea of a stomach as a vital organ as the stomach has been entirely removed, the œsophagus being united with the small intestine. Dr. Schlatter of the University of Zurich recently removed a woman's stomach joining together the approaches to it. He reports his patient well and able to enjoy health without any stomach. Some think that this is not a proof of ability to do without the stomach normally as the stomach in this case was so impaired as to be of no use anyhow. It gives evidence of the extension of the principle of functional sympathy to the stomach.

The digestive process is modified in some animals. In the stomach of the pig we find two parts in the stomach, one part on the left side containing the œsophagus, one part on the right forming the stomach proper. In the former part there is a firmer mucous lining, much less moist with no glands but covered with small papillary eminences. In the other part the mucous lining is very thick, containing glands very much like the fundus glands. In the horse the stomach is very small compared with the amount of food used. The right portion in the true stomach, the left portion being the œsophageal part covered with a layer of mucous membrane very white in color. The pyloric orifice is much less tightly closed than in the human subject permitting the free passage of the food substance into the small intestine. In the ruminating animals the stomach is much more complex. There are four parts or sacs; (1) the rumen; (2) the reticulum; (3) the omasum; (4) the true stomach. The rumen is a very large sac covered with mucous containing conical papillary eminences. This is connected with the lower end of the œsophagus and also with the reticulum, being divided from the latter by a strong band of fibres from the omasum and the true stomach similar to those found in the human subject in connection with the cardiac part of the stomach. The reticulum is in the form of network consisting of a large number of cells the muscular coat being very strong and its fibres being continuous with the œsophagus. The omasum has a firm wall with two openings into the reticulum and true stomach. The mucous lining consists of leaves folding over into the sac, these being covered with round papillae. The true stomach is like the stomach in other animals with the fundus and pyloric glands. The food when roughly broken up and forming boli pass down the œsophagus into the rumen. Fluids may pass immediately into the omasum, if the amount of fluid is excessive a part may pass to the reticulum, the more viscous fluids adhering to the œsophageal opening or entering the omasum. The food is mixed with saliva passing into the rumen where the food is moved about and broken up and softened, fermentation taking place. After the complete mixing, rumination begins. The action is almost identical with vomiting. The rumen muscular walls contract and the reticulum and diaphragm also contract with the muscles of the abdomen, resulting in the driving of the food into the mouth, the nasal opening being closed. It now becomes masticated and insalivated afterwards passing down the œsophagus passing in-

to the omasum, the more fluid matters passing almost directly into the true stomach while the rougher elements are passed through a process of filtration among the folds of the omasum. The fluid extracted passes into the true stomach and the solid matters are also driven into the true stomach by the force of the contraction of the walls. In the true stomach digestion proceeds as in the human stomach.

THE SMALL INTESTINE:—The chyme formed in the stomach is carried through the pyloric opening and is carried into the small intestine by peristaltic action. These peristaltic movements take place from above downwards, the undulation beginning at the pylorus and extending down, although there are contractions originating all along the intestines. These peristaltic movements take place successively with intervening periods of rest. These movements secure the slow passage of the chyme along the small intestine and its mixture with the three juices, the bile, pancreatic and intestinal juices. There is also a process of absorption taking place in the intestine, the water, fatty and soluble matters being given up in the passage through the intestine.

In the intestinal coat there are two nervous plexuses, the one in the connective tissue or the sub-mucous layer and one lying between the two muscular layers. There are also fibres of the pneumogastrics and splanchnic sympathetics. By the severance of the intestine from nervous connection with the central system and stimulation of the intestine, the peristaltic action may be produced, indicating that the ganglia within the intestine act as independent centers in producing these movements. These movements depend not only upon nervous stimulation but also upon the condition and amount of the blood supply. The peristaltic action is increased by anaemic conditions and also by plethoric conditions of the blood, in both cases there is an excess of $CO_2$ and deficiency of Oxygen, the gas acting as a stimulant. When the circulation is partly suspended or when a severe hemorrhage withdraws a large quantity of the blood the movement is increased. During the digestive process there is an extra blood supply this acting as a stimulant upon the action. If the stimulation is increased to excess, paralysis ensues and the action is suspended. An excessive blood flow amounting to congestion or inflamation will have the same effect If the pneumogastrics be stimulated the action is increased, whereas the stimulation of the sympathetics stops the contraction indicating that the pneumogastric acts as an accelerator of the centers in the intestinal walls while the sympathetics inhibit the action of these centers, this inhibition depending upon the character of the blood. If the blood is normal as between arterial and venous, inhibition is changed into acceleration. This seems to indicate the presence of two kinds of fibres in the sympathetics, the inhibiting fibres being contracted by the venosity of the blood. The higher psychic centers may also influence the peristaltic action as in cases of emotional conditions and nervous diseases producing constipaatory conditions. The stimulation is aroused by strangulations originating in the brain influencing the vaso motor center, causing constriction of the vessels in the abdominal regions resulting in the

anaemic condition of the blood gives rise to strong peristaltic actions.

BILE;—In the liver we find a number of lobules, each lobule being supplied with blood from the portal and hepatic circulations. From the portal circulation there comes blood which has been circulated in the stomach and intestines bearing substances absorbed from these organs, while hepatic circulation conveys arterial blood for the nutriment of the organ itself and its vessels. From the portal blood the lobular cells secrete substances which are given off into the ducts from the formation of bile. This blood when robbed of these matters returns through the hepatic vein to the heart. The portal blood entering the liver contains a larger amount of albumen, haemogloblin, fat, salts and water and less cholesterin and lecithin than that returned to the heart. The portal blood brought to the liver also contains saccharine matter taken from the carbohydrates while the blood returned to the heart contains sugar from glycogen. The lobular cells therefore are the seat of bile secretion and also that of glycogenesis. This last belongs to the field of metabolism. The bile is both a digestive secretion and an excretion, the former being used in the digestive process and the latter excreted as excess in the faeces. The bile may be best secured by means of a fistulary operation. The bile when fresh is a fluid of a golden red or brownish yellow color. It has a strange odor, especially if hot. and a very bitter taste. It contains some gall cells and some mucous corpuscles usually. Its specific gravity is about 1030. In the gall bladder the bile is mixed with a considerable quantity of mucous, of a darker color and more viscid. Bile yields in the case of man from 13 to 15 p. c. of solid matter. On analysis in 100 parts of bile there have been found 86.3 p. c. of water, 13.7 p. c. of solids and of these solids 8.2 p. c. of bile salts, 2.5 p. c. of cholesterin, lecithin, fatty substances, 2.2 p.c. of mucous and bile pigment and .8 of inorganic salts. Among the solid matters we find,

1. Bile acids. Tanrochloric acid found in great abundance and glycocholate acid in small quantities in human bile. These combine with sodium to form salts.

2. Bile pigments. Bilirubin and biliverdin. The former is believed to be derived from the red coloring matter of the blood, the latter by the oxidation of bilirubin. The bilirubin is kept in solution in the bile by the sodium salts of the bile acid.

3. Cholestrin kept in solution in the bile by the bile salts. This is the chief element found in gall stones.

4. The mineral salts, including chloride of sodium and potassium and the phosphate of sodium, calcium, magnesia with traces of iron oxide, salica, manganese and copper.

5. Gases. The bile contains sometimes a large p. c. of $CO_2$ varying from 5 to 50 p. c. and small quantities of oxygen and nitrogen.

The secretion of bile is continuous but the quantity formed when the stomach is empty is small. Only a low pressure is necessary for bile secretion for it is not due to the pressure, not being a process of osmosis but of secretion in the hepatic cells. It is largely increased during the digestive process, this secretion beginning to increase almost immediately

after taking a meal, reaching its highest point about the third or fourth hour and after gradually diminishing for a few hours, then increasing till about the tenth hour after which it lessens. The amount of food influences the bile secretion, especially in the case of animal food when the secretion is increased, a food consisting very largely of fats diminishing the secretion. The secretion is also effected by the blood flow in the capillaries. If the blood is injected into the veins it is increased and if blood is taken from the arteries it is diminished. If the portal vein be ligatured the secretion will diminish until it ceases altogether, causing death. While the blood pressure in the capillary does not cause the secretion, the velocity of the blood current through the capillaries has a bearing upon the secretion because the action of the hepatic cells depends upon the circulation of the blood through them. If the blood pressure in the bile ducts increases beyond 15 mm. of mercury the secretion of the bile continues but its flow is arrested in the ducts, the bile flow taking place into the blood through the lymphatics, the bile pigment giving to the skin the peculiar jaundice color. The same result may follow from a ligature of the bile duct, the process however requires three or four days. Associated with jaundice is a condition of constipation due to the lessening of peristaltic action, the faeces hard and yellow colored. An effect is noticeable upon the activity of the heart which is much diminished and also the respirations become slower.

The formation of bile takes place in connection with the hepatic cells which are closely related to the blood and the bile capillaries. The cells are polygonal in shape, around the sides being found the bile capillaries, at each of the pointed surfaces being found the blood capillaries. The bile capillaries are much smaller than the blood capillaries. That the bile is formed in these cells is evident from the fact

1. That if the liver be removed the bile acids and bile pigments are not found in the blood.

2. The bile acids and pigments are not found in connection with any part of the body. The bilirubin arises in connection with the disintegration of the haemoglobin. In connection with blood clotting the bilirubin assumes the crystalline form of haematoidin. The substance when hydrated appears in the faeces as stercobilin and in urine as urobilin. When the bile is formed in connection with the cells it is pressed out partly in connection with respiratory movements and partly by muscular activity in connection with the ducts and the gall bladder. The bile secretion is continuous. It is normally small when the stomach is inactive. Immediately after taking a meal the amount is very much increased and this increase is maintained for some hours. It is said that in 24 hours 2 1-2 pounds are secreted and that the secretion is much more plentiful after partaking of proteid food. The bile accumulates in the gall bladder and it is ejected into the intestine appearing to be a reflex act, the stimulus being the acid chyme for it is known that the entrance of an acid into the small intestine is at once followed by a gush of bile, while no such results follow the admission of an alkaline fluid into the small intestine. Nervous influence upon the bile secretion is very obscure. The vaso-motor fibres

are found in the pneumogastrics and the splanchnic sympathetics. If the splanchnics are divided or the pneumogastrics in the neck be sected the liver passes into a stage of congestion.

When the bile comes into the small intestine it has very little effect upon the chyme. In the large intestine a part of it becomes decomposed. The biliary acids are divided up into glycosin and taurine, cholalic acid; the bile pigment into hydrobilirubin and urobilin to be again absorbed so as to form the urine pigment. Part of the bile acid is united with alkalies in the formation of soap. The faeces excrete cholesterine, mucin leichtin.

Upon the albuminous or proteid constituents of food bile has no effect unless that by its alkaline reaction it neutralizes the acid chyme and causes the precipitation of any peptone present. The bile prevents the digestion of albuminous matter by the gastric juice, at the same time separating the peptone from albumen for the digestive action of the pancreatic juice. Upon the carbohydrates the bile has no effect, its only effect being to transform the starch solutions into sugar. Upon the fats bile has considerable digestive power. When the fatty solids are liberated by the pancreatic fluid, the bile combines with them to form soaps or emulsions. The fatty acids thus decomposed dissolve the bile salts uniting with the alkaline bases, form the soaps, the soaps aiding in emulsifying the fats. The fats readily pass through the mucous membrane moistened with bile. Hence bile assists the absorption of fats by moisteniug the mucous membrane of the intestine. Bile also stimulates the peristaltic movements of the intestine. If the bile is diminished then peristaltic action is lessened and the faeces become dry.

2. Pancreatic juice. This fluid may be obtained by the introduction of a canula into the duct. It is a clear colorless fluid, viscid, under the influence of heat becoming coagulated. It has a decided alkaline reaction and contains about 10 p. c. of solids. It contains a large proportion of albumin and a quantity of salts, such as sodium chloride, phosphates and carbonates, together with small quantities of soapy substance and nitrogenous matters like leusin and xanthin etc.. and also the ferments. During fasting little or no pancreatic juice is secreted but as soon as food is taken the secretion of the juice commences and continues for hours. It is estimated that in twenty-four hours considerably over 100 grams are secreted. During the digestive intervals a small quantity is secreted. At the beginning of digestion it seems to be more viscid, becoming more free at the end of digestion. The use of a large proportion of good and nutritious food increases the secretion. The secretion seems to take place under the influence of pressure. When inactive the pancreas is pale, when active it becomes reddish, the blood vessels being full and characterized by pulsations. The cells in the gland become larger as the secretion takes place. The pancreatic juice acts differently upon the different foods. On starchy foods it acts very actively, rapidly converting by action of an amylolytic ferment starch into sugar more rapidly than during the process of insalivation. Any form of starch is thus quickly acted upon by pancreatic juice. On fats it has a two fold action: (1) It emul-

sifies them, the emulsion representing the fatty matters in a fine state of division. (2) It splits up neutral fats into their respective acids and glycerine and the free fatty acids then combine with sodium salts to form soap. The emulsifying power of the pancreatic juice depends upon vicidity, on the presence of carbonates and on the formation of the soaps through the action upon the fatty substances. The bile if present in the pancreatic juice assists in the process of emulsification. The proteids are converted by the pancreatic juice into peptones, but the amount of peptone produced does not correspond with the amount of proteid matter acted upon. This is due to the fact that while the albumin is changed into peptone a number of other substances is formed, the peptones becoming partially changed into leusin and tryosine, these last being changed into indol and other substances which have a characteristic faecal odor. Thus the pancreatic digestion of proteids differs from the gastric digestion of the same substances. For the action of pepsin upon proteid acids must be present while the pancreatic juice is most active when an alkaline is present and it is retarded or hindered by neutralization or acidification. The conversion of starch into sugar, the action upon fats, the formation of peptones from proteids, each of these results is believed to be due to the action of special ferment present in the pancreatic juice· This ferment is the proteolytic ferment tripsin. It is peculiarly active in alkaline solutions, decomposing the albumins. The tripsin is formed by the decomposition of tripsinogen. Under the action of tripsin the proteids are changed into triptones or "haemipeptones" as Halliburtion calls them. They are readily dissolved in water and by a weak solution of copper sulphate yield in reaction a deep purple red color. The decomposition yield the amido-acids, leusin and tryosin and odorous substances of phenol and indol. This latter substance it is claimedis produced under the influenc not of the unorganized ferments but of the organized ferment, micro-organisms being necessary for its production.

3. The intestinal juice. This juice is belived to be secreted by the glands of Brunner and Lieberkuhn. The information regarding this juice is limited chiefly on account of the difficulty of obtaining it pure. It is a clear, viscid fluid, with a palish yellow color and a strong alkaline reaction. It is freely coagulated by and under acid influence having a specific gravity of 1010. It contains a small percentage from 1 to 2 1-2 p. c. of solid, chiefly albumen, mucin with the carbonate of soda and sodium chloride. The ferment invertin converts cane into sugar inverted. It is variously described as having a digestive influence over proteids, fats and carbohydrates, others however claiming that its action is confined to the conversion of starch into dextrine and maltose. The mucin contained in the fluid acts as a lubricant upon the intestine, smoothing it so as to permit the contents to pass freely. As soon as the chyme passes into the intestine the gastric juice ceases to act upon it, the acidity of the chyme producing the flow of bile, pancreatic juice and intestinal juice. The alkalinity of these juices neutralizes the acidity of the chyme, producing the normal alkalinity in the small intestine. In the small in-

testine all the food elements become changed so as to be prepared for absorption. The hydrochloric acid of the gastric juice precipitates pepsin and glycocholate, the taurocholate precipitating the albumen not transformed into peptones, the peptone and tripeptones remaining in solution. At the upper part of the intestine the chyme is a pale yellow color due to the bile influence, at the lower part it is much paler. As it passes down the alkalinity increases the action of the juices, the digestive process being nearly completed, bearing very small quantities of undigested food. Under the influence of the alkalinity the tripeptone digestion takes place. During the progress of these various changes peristaltic action of these muscular fibres propels the chyme along the course of the intestine, the absorption of the soluble matters taking place in connection with the blood vessels and the mucous projection of the intestine. Thus the chyme is gradually transformed and diminished, these processes preparing it for passage into the great intestine.

Changes in the Large Intestine:—By the absorption of the soluble elements from the chyme it is lessened in quantity and passing into the great intestine to be subjected to the action of secretion arising from glands similar to the small intestine. As in the small intestine there are movements of the intestinal contents due to the peristaltic contraction of the muscular fibres of the bowels. The movement however, is much slower than in the small intestine as the bowel is not so free being in the greater part of its extent fixed by the peritoneum. The passage of the contents through the large intestine takes a much longer time than is occupied in the small intestine, although the great intestine is about one-third the length of the small one. It is estimated that from 12 to 18 hours are occupied in the passage through this large intestine. This length of time includes the long time during which the substances continue in the caecum becoming more solid on account of the water being absorbed. The nervous connection with the large intestine is unknown. The excitation of the pneumogastric tends to stimulate while the excitation of the splanchnic does not stimulate the activity of the large intestine. No digestive process goes on in the large intestine. The contents are of a distinctly faecal character and are acid in reaction, this being due to the acid fermentation of the intestinal contents and not to any acid secretion yielded by the glands in the intestinal mucous membrane. In the large intestine the contents are alkaline towards the walls, the secretion of the intestinal glands being alkaline in reaction while towards the middle of the intestine and away from the walls they are acid. In the human subject the intestinal changes consists of the formation out of the waste elements of the food, of the bile and other secretions, a faecal substance. In the caecum the waste matters become closely packed together on account of the absence of peristaltic action. The fermentation going on produces certain acids, lactic acid, butyric acid and also by the generation of certain gases as hydrogen, sulphretted hydrogen etc. The water becomes absorbed by the blood vessels. In this way the intestinal contents become more and more solid, the water being absorbed. Putrefactive changes also give rise to the form-

ation of certain other acids, such as palmatic acid, together with odorous substances phenol, cresol, indol, skatal. The bile that passes down into the large intestine become changed into taurin, glycocin, cholalic acid, which together with the pigments and acids of the bile are found in the faeces. These faeces have a characteristic which varies in the individual and at different times. This aroma arises from the decomposition of the contents of the stomach and intestine. These may be either acid or alkaline or neutral. In the case of dieting upon the carbohydrates the faeces become characteristically acid, if the diet is albuminous they become alkaline. The color also varies with the food, a dark color arising in the case of an animal diet, a vegetable diet a light color and in a mixed animal and vegetable diet a yellowish brown. In jaundiced conditions the faeces become a dark yellow. Microscopic examinations disclosed the presence of tissues in fragmentary stages, these tissues varying with the diet. Among the other substances found are fatty cells, starchy globules, fibres in different stages of decomposition. There may also be found the acids, pigments and soaps found in connection with the gastric and other juices. In a mixed diet they contain about 75 p. c. of water while in diet upon animal food this is usually reduced to 50 or 60 p. c., about 25 p. c. being solid matter of which about 5 p. c. consists of salts, chiefly the phosphate of ammonia and magnesia. The normal human subject is estimated to pass about 150 to 200 grams daily in the form of faeces. This amount, however, depends somewhat upon the nature of the food, in vegetable diet the amount being largely increased. In the rectum the faeces remain a variable time and they are expelled as the result of relaxation of the internal sphincter, action of the walls of the retum and of the abdominal muscles assisted by the fixed action of the diaphragm. The act of defaecation is under the control of a special nervous centre situated in the lumbar portion of the spinal cord, this centre being subject to the influence of the higher centres. This is evident from the fact that in comatose conditions the sphincters become paralysed and defaecation is no longer under the control of the will, being entirely involuntary. This, however, is disputed, the paralysis of the sphincter being said by some physiologists to be due to the inhibition of the lumbar centres. In the rectal movements we find the distinct action of the longitudinal and transverse fibres, the longitudinal movements being directed from above downwards cause the shortening of the rectum, the transverse movements traveling the same direction but following the contractions causing a narrowing of the rectum and thus pushing onwards the matter within the rectum.

Absorption:—The food substances we have considered in the different stages of digestion, the elements being separated in such a way as to leave the nutriment in the fluid solution. This prepares the substance for absorption. To this process of absorption apply all of the principles of physics bearing upon diffusion. These nutritious matters are as yet outside the body in the passage through the alimentary canal. So we have seen digestion consists of the conversion of proteids which are diffusible

into diffusible peptones and triptones annd the emulsification of fats so as to prepare for the absorption process. This process takes place (1) in connection with the alimentary canal, (2) in connection with other organs.

1. During digestion in the stomach water, salts, sugar and peptones pass into the blood vessels in the gastric mucous membranes and are by them conveyed to the liver. Absorption takes place in the stomach and the intestines, but it is especially in the small intestines that absorption takes place in connection with the capillaries of the system the absorbed substances being carried into the liver and by the lacteals into the lymphatic system. These two channels represent the great fluid circulations of the body and the lymph.

2. The Blood. The mucous lining of the stomach and the intestines is abundantly provided with blood vessels lying directly underneath epithelium lining. In the stomach the capillaries are found to form net works of irregular formation in the small intestines, the capillary plexuses exist in the form of loops, changed into the villi while in the large intestine the net work of capillaries is regular. These capillaries are normally filled with blood separated by the vessel walls from the chyme. In this way by the close connection of the blood and the solution containing certain substances results in the passage by absorption into the blood of water, salts, peptones, these passing in the blood to the liver. This interchange between the blood and the lymph in their respective systems and the fluid contents of the stomach and the intestines takes place on the basis of the principles of diffusion. When the blood and the lymph become defficient in water, salt and saccharine matter these substances pass from the fluid in the intestines. The diffusion takes place on the basis of the difference in the substances found in the respective fluids, the rapidity of the diffusion process depending to some extent upon the motions of the fluids, the peristaltic action of the stomach and intestine, keeping the digestive fluids in constant movement. This process of diffusion does not account for the absorption of fatty substances and albumin. Albumin will not readily pass through a membrae by diffusion and only if fluid upon one side of the membrae is rich in albumin. There is a large per cent. of albumin in the blood and lymph, about seven and three per cent. respectively. This albuminous matter however by the digestive process is changed into peptones, these being readily soluble in water and thus prepared for absorption in connection with the cellular walls of the vessels. The mucous lining of the small intestine is covered over with small projections of the mucous membrane, very numerous in the human subject, being said to number four million, these form conical or cylindrical processes projecting about one mm. out from the mucous lining. They consist of delicate adenoid tissue. In the centre of the villi we find an open space freely connected with the retiform tissue towards the base, the villus becomes lacteal, the villus being abundantly supplied with blood vessels. On the surface of the villus there is a delicate covering of epithelial cells. During the process of absorption in connection with fatty substances, fat particles are found in these cells or at the cell margins. The fat

molecules pass from the fluis in the intestine into the lacteal, some physiologists suppose that they are driven through the cells or between the cells by the force of peristaltic movements. It is more likely however that these cells absorb the fat and pass then through the cell filaments, these filaments being emptied of their fatty contents by a series of sucking movements. The filaments of these cells are supposed by Schafer to be continuous with the filaments of the lymph cells, permitting a free passage through the double cells from the intestine to the lymph vessels. The blood vessels also absorb peptones and through other substances produced by the digestive processes, this absorbtion through the blood vessels and the cells being carried on within the limits of their capacity of absorption, the surplus that cannot be thus absorbed being excreted in the faeces.

3. Lymph and Chyle:—The lacteals mentioned in connection with absorption of fat represent the part of the lymphatic system found in connection with the small intestine. These lacteals differ only from the general lymphatics in the character of the fluid, chyle, of a milky white color, found in the lymphatics. The lymphatic system originates in the minute capillary vessels, these vessels being found in the human subject all over the body wherever connective tissue is found in which are the interspaces in which the lymph is collected. The lymph capillaries are joined together into bundles passing into the smaller lymphatic vessels running through a bed of connective tissue until after passing through the larger lymphatics where they are united with the two main lymphatic ducts, the thoracic duct and the right lymphatic opening into the junction of the subclavian and jugular veins on the left and right sides.

The spaces in connection with the connective tissue of the body constitute the origins of the lymphatic system. Certain constituent elements of the blood plasma ooze through the vessel walls into those spaces. From these spaces there is a constant flow of the lymphoid through the lymph capillaries into the larger lymphatic vessels through the thoracic duct and the great lymphatic trunk into the blood circulation. The lymph, first of all, is presented in those inter-spaces between the tissues, those inter-spaces being in constant communication with one an other, and also with the small lymphatics, which, as they pass to the larger lymphatics assume the form of lymphatic veins. Those lymphatic veins have delicate walls and are arranged with a large number of semilunar valves with dilitation in the lymphatic vessels above the valves. These valves always open away from the inter-spaces and thus render efficient assistance to the lymph flow in its forward movements from the interspaces toward the larger lymphatic vessels. The smaller lymphatics are joined together in the formation of larger lymphatics. These larger lymphatics being all united together with the two main lymphatic trunks, the thoracic duct and the right lymphatic duct. The right lymphatic duct is short, being the terminal of the lymphatics of only a small portion of the lymphatic system. All the other lymphatics terminating in the thoracic duct. The thoracic duct runs along the entire extent of the thoracic cavity. These two main ducts have very delicate walls, also, a valvular arrange-

ment so as to promote the movement of the lymph away from the smaller lymphatics and to prevent lymphatic regurgitation. The two main ducts terminate on the two sides of the neck where, at least in the human subject, the duct cavity unites with the junction of the subclavian and the internal jugular veins, in the formation of the innominate vein. At this junction of the ducts with the veins there is a valvular arrangement permitting of the passage of the lymph into the veins but preventing the passage of the blood from the veins into the duct. Throughout the serous cavities of the body there also, are found the beginnings and terminals of the lymphatic systems, these serous cavities being large surfaces in the lymphatic circulation here and there in the course of this lymphatc glands through which the smaller lymphatics pass.

These glands present, at least from the standpoint of the circulation, a resistance very similar to the peripheral resistance found in the capillaries in connection with the blood circulation. Thus the analogy between the lymph in the lymphatic circulation and the blood in the blood circulation is almost complete. The lymph circulates from the lymph spaces, through the lymphatic vessels, and the lymphatics terminate in the venous junction in the neck, and thus is brought into close connection with the blood system. The tissues of the body are nourished by the fluid that is transuded through the capillary walls. Part of this fluid passes into the living tissue, is carried away in the form of waste. In all the tissues of the body that receive blood, the lymphatics are found very abundant, particularly in the region of the arteries and of the veins. The lymph does not pass directly into the blood, but through the lymphatic glands. The lymphatic vessels contain delicate walls from 2-10 to 6-10 m.m. in diameter. These delicate walls of the lymph vessels consist of three coats.

I. The intima of endothium and elastic fibres.

2. The media of transverse fibres and also elastic fibres.

3. Adventitia consists of connective tissue, interlaced by elastic tissues and smooth muscular fibres. The minute lymphatic vessels consist entirely of endothelium cells. These endothelium cells being formed into capillary bundles, all of them opening toward the periphery. The fluid which has been exuded from the blood vessels, passes into these minute lymphatic vessels by the process of osmosis or as some physiologists think, through the lymphatic openings that are embedded in the tissues. According to some physiologists, the process of osmosis is not correct; they say that in the very minute lymphatic vessels there are delicate mouths, or openings which pass down into the lymphatic spaces, and each of these openings represents a mouth through which the lymph passes out of the spaces into the minute capillaries.

Along the lymphatic path there are, as we have seen, lymphatic glands, small, rounded bodies of varying sizes, representing the collection of the lymphatic vessels at certain points along the lymph path. On the one side of these glands there is a small fissure in which the lymph vessels are found to arise. The gland is covered with a sheath of connective tissue, and the gland is divided into a number of sections, forming a

dense plexus in which there are embedded the smaller lymphatics, and from which arise the larger lymphatics. These lymphatic glands are very freely supplied with blood vessels, either on the surface, or in the fissure.

Nerves, also find connection in the gland, in what way this connection is established is not known. The capillary system brings the blood to the different tissues and as the capillary walls are delicate there is a free osmosis through these walls under the pressure of blood in the capillaries. Under this filtration process the water in the blood together with the saline substances in solution pass freely without carrying any of the albuminous substances along. It is thus laden with oxygen which is of value in the process of respiration and nutrition for the upbuilding of the tissues. After the tissues take up what is necessary for them the lymphatics collect the excess carrying it off in the lymphatic system. Where there is a large excess of this fluid transuded from the blood, too large to be appropriated by the tissues and to be taken up by the lymphatics we have a conditition superinduced in the tissues to which the name of œdema is applied. This same condition may be produced by the constriction or the obstruction of the lymphatic circulation, producing a swollen condition of the tissues—for example in dropsical conditions. Thus, the lymph originates partly fom the blood and partly from the tissues of the body. The lymph passing through the glands, washing out these glands and in this way often collecting in the lymph stream a large number of lymph corpuscles. The lymph, itself, is a clear, colorless or pale yellowish fluid transparent or slightly opalescent, coagulating very quickly under the influence of fibrin, this fibrin being the same as the fibrin that we find in connection with the blood. The lymph clotting being almost the same as blood clotting. The chemical composition of lymph varies very much, resembling the blood plasma except in one particular, its poverty of albumin. The specific gravity of the lymph is about 1017 varying to about 1025. When the lymph is microscopically examined it is found to to contain a large number of lymph corpuscles and sometimes a few red corpuscles. These corpuscles are smaller than the white blood corpuscles, although some physiologists have said they are identical. The lymph corpuscles are globular in shape, consisting of a large nucleus with a narrow granular margin varying in size from 5 to 15 micra. In the lymph there is found about 1-10 per cent of fibrin the ferment of the blood and the ferment of the lymph. As the lymph is transuded from various vessels and tissues of the body it varies very much in its character as it is found in the different parts of the body.

The solid matter is usually much less than that found in the blood, being not more than 5 or 6 p. c. of the solid matter. The venous blood is found to be much richer in solid matter, than the arterial blood, because the fluid part has been partly transuded into the lymph. There is found in the lymph varying percentages of albumen, smaller quantities of extractives, a small proportion of salts together with slight traces of fatty substances with a large percentage of $CO_2$ and only a small trace of oxygen. In a hundred parts of human lymph it is estimated there are 95 p. c. of water and 5 p. c. of

solid matter. Of this 5 p. c. of solid matter, 4 1-10 p. c. of albumen; 5-10 p. c. of the salts, 3-10 of the extractives and 1-10 the fibrin, with a trace of fat. In the lymph spaces, capillaries and minute vessels there is a large percentage of water, whereas, in the larger lymphatics there is an increasing percentage of solid, the number of corpuscles increasing in the passage through the lymphatic glands. The perichoroidal and pericorneal fluids are also lymph, containing at times less and at times more solid matter than the normal lymph, otherwise possessing the normal characteristics in corpuscles and composition. The amount of lymph varies from time to time in different regions Active exercise increases the flow of lymph, as also the hanging of the hand, the swollen appearance resulting from the increase in lymph and blood in the veins. Similarly the skin and tissues may become shrunken on account of the absence of the lymph. In 24 hours it is estimated that lymph is formed equal to 1-10 of the body weight. The lymph is so important in sufficient quantities that death very soon supervenes if the lymph loss becomes excessive, so that its existance in normal condition and its circulation are necessary for life. In man there are said to be no lymph hearts, such as have been found in connection with the frog, these lymph hearts in the frog giving rise to certain rhythmical contractions. According to some physiologists, there do exist lymph hearts in the human subject. Where these lymph hearts exist they consist of small dilitations with striated muscle fibres in the walls. Where they exist their pulsation is not in any way connected with the heart beat. In connection with the lymphatics unstriped muscle fibres are found in the walls and it is said that pulsations take place in connection with the muscle fibres as it is more probable that these fibres regulate the calibre of the lymphatics under the influence of the nervous system.

The lymph flows with great rapidity through the thoracic duct into which the lymph is continuously being poured from the smaller lymph vessels and also from the lymph spaces. The forward movement of the lymph depends upon a number of circumstances. The lymph moves, as we have seen before, from the roots of the vessels toward their trunks. This movement is slow as compared with the movements of the blood; hence, it is estimated by the physiologists that in the lymphatics of the neck, for example, the lymph flow represents 4 mm. per second. We have four circumstances or conditions that influence the movement of the lymph, these we will specify:

1. The valvular arrangement of the lymphatic system. As in the case of the veins, the lymphatic vessels are materially influenced by the pressure of the skeletal muscles. The valves of the lymphatic system prevent the lymph from flowing backward, always forcing the lymph forward toward the venous system and preventing the regurgitation of the lymph. In the case of a divided lymphatic vessel the simple motion of bending or straightening a limb, produces a profuse discharge of the lymph, this discharge being due to the pressure exerted by the muscles. In this way muscular movements tend to increase all the time the lymph movement, along the lymphatic path. The entrance from the thoracic duct into the venous system is protected also by a valve so that the

lymph must flow freely in one direction from the lymphatic system into the enous circulation and the blood cannot flow from the venous system into the lymphatic system.

2. Lymph pressure. The pressure of the blood in the capillaries and in the smaller vessels is very much larger than in the larger arteries, producing, as we saw, the blood flow from the capillary system always toward the heart. In the lymph spaces the lymph also is subject to considerable pressure, along the lymph path, also. the lymph flow is effectively sustained by the valves, as we have seen, which keep it up in one direction. In addition to this, at the close of the lymphatic system in close proximity to the venous system the pressure always varies from a slight positive to slight negative. In the lymph spaces where lymph originates. the pressure is estimated about one half of the blood pressure in the capillaries; that is from 12 to 27 mm. of mercury. Along the lymph path there is, also, a resistance continuously met with, causing the lymph to accumulate in the lymph spaces of the tissues. This accumulation under the influence of resistance being balanced normally by the muscular activity of pressure of the muscles causing the steady onward flow of the lymph along the lymphatic path. On account of the difference in the pressure, between the blood and the lymph, in the capillary system, exudation takes place from the blood to the lymph spaces.

This pressure which causes the transudation of blood from the blood into the lymph spaces marks the highest point in the lymph pressure, determining as we have said, the origin of the lymph current away from the lymph spaces that are found in the tissues toward a lower pressure, which is found at the junction of the lynphatic and the venous systems. This difference in pressure at the origin, and at the close of the lymphatic current always determines the lymph flow in the one direction toward the venous system.

3. The Influence of respiration. At every inspiration the pressure in the large veins near the heart becomes negative, sucking, as we have seen, the venous blood, always toward the heart. Side by side, with this suction action that we find in the venous system. we find the suction force of inspiration, also pulling the lymph from the openings of the thoracic duct and the right lymphatic duct into the venous system. The thoracic duct lies inside the thoracic cavity so that at each inspiration the duct becomes somewhat expanded, setting up in this way, a certain suction action reaching backward to the lymphatic vessels that are outside the thoracic cavity, and always tending to pull the lymph, first of all, toward the great duct, and then from the great duct into the venous circulation.

4. In addition to these three influences we have also, two other influences upon which physiologists, however, are not fully agreed. These two influences are,

1. The pressure arising from the osmosis.

2. The pressure arising from the muscular contractions or the lymphatic walls. The blood pressure in the capillaries throws out the fluid as we have seen, into the lymph spaces, thus originating, at least, the lymph flow from these lymph spaces. The increase of blood pressure increases at the same time and the decrease of the blood pressure decreases at the same time the current of

the lymph, so that the flow of the lymph depends largely, if not altogether, on this origin in the pressure of the flow in the capillaries. The walls of the lymph vessels, as we said before, are muscular, especially at the valvular regions. These dilated regions are said to contract after the same fashion as the heart during systole. This adding to the force which drives the lymph always onward from the lymph spaces to the larger lymph vessels. These movements, however, in the subject, are only ideals, because so far, no experiments have been made to indicate that there are such lymph hearts.

These lymph hearts, as we said before do exist in the frog, but whether they exist in the human or not is simply a matter of theory. From the standpoint of theory the pulsation of these lymph hearts seems to bear upon the lymph in its ownward movement.

The combination of these influences tends to produce a steady lymph flow toward the larger duct, even over the force of gravity, this flow is steadily maintained from the lower limbs; especially by the valvular arrangement, preventing a backward flow. It is also supposed by some Physiologists that from the analogy of the blood circulation that the nervous system exercises an immediate influence on the distribution of the lymph and in its circulation through the lymphatic system. This, however, has not yet been demonstrated by physiological experiments. In the passage from the blood to the lymph there are two characteristic stages. (1st) The passage from the blood to the lymph spaces and (2d) The passage from the lymph spaces to the lymph vessels. These lymph vessels are not always closely connected with the blood vessels. Hence, this has raised a difficulty in Physiology to explain the flow of the lymph out of the spaces into the lymph capillaries. Attempts have been made by some Physiologists to apply the principles of diffusion and of the filtration to the passage of the lymph from the lymph spaces into the lymph vessels. The passage, however, through the vessel wall cannot be explained either by principle of diffusion or by the principle of filtration. The explanation becomes more difficult when we consider that a double passage takes place between the blood and the lymph spaces and between the lymph spaces and the blood, indicating that in addition to a purely physical principle of diffusion or filtration we must always take account of the physiological condition of the vessel walls. According to some Physiologists the same process takes place in the passage of the lymph from the lymph spaces to the lymph capillaries as takes place in the passage of fluid from the blood into the lymph spaces. This, however, is incorrect, because there are openings at certain points along the lymph capillaries, into the lymph spaces forming a direct passage from the lymph spaces into the capillaries, whereas, there are no openings between the blood and lymph spaces unless through the walls, as we saw before, when the fluid and sometimes the white corpuscles and sometimes the red corpuscles press their way through between the magins of the cells which line the walls of these blood vessels.

The quantity of lymph varies, the tissues demanding in certain circumstances more lymph, although it never normally exceeds a certain definite quantity. This limit may be exceeded in pathological

conditions resulting in œdema. Oedema may be produced in one of two ways: an excessive transudation from the blood into the lymph spaces or by some obstruction to the transudation from the lymph spaces to the lymph capillaries. In the latter case an obstruction does not materially affect the lymph-flow as the anastomosis of the lymph vessels like the venous anastomosis opens up a free passage for the lymph in another path toward the ducts. Thus the real cause of œdematous condition is excessive transudation. These, however, belong to the field of pathology. The importance of the lymph circulation is evident from the close relation it bears to the blood circulation, from the amount of fluid that daily passes through the lymph circulation, and from the dangerous effects resulting from the excessive accumulation of lymph.

The blood circulation depends upon certain factors, all of which vary more or less, the heart-beat, the peripheral resistance, the length of the vessels and their calibre, the elasticity of the walls and the valvular mechanism. These under the force of muscular contraction and relaxation and under the influence of the nervous system keep the blood in proportional distribution and normal circulation in the body. The quantity and quality of the blood, also exercise an influence on the circulation. It seems remarkable that the heart should go on continuously resisting temporary irregularities and overcoming temporary obstructions, and at last without almost any notice cease to beat and suspend life. Each heart-beat, however, involves an effort, and the effort is one to sustain life against the odds presented by all the resistances of the system. Thus the maintenance of life through the circulation of the blood with the analogous circulation of the lymph represents the most important factor in life. When we add to this the influence exerted by the nervous system upon the circulation keeping up the tonic condition of the vessels, and maintaining the distribution and circulation of the blood, we have the foundation factors of the life in the human system. Along the entire blood path, then move influences that during life are constantly playing a most important part in the upbuilding, general development and continued existence of the human life. If the statement of Dr. A. T. Still is correct, and we accept it with all the force of his life study behind it, "that a natural flow of blood is health; and that disease is the effect of a local or general disturbance of blood," then you can understand and appreciate the reasons that have led us to devote such a large portion of our time to the exhaustive study of the blood and the circulation, and at the same time feel that when we have completely mastered this subject, we have laid a solid foundation for the rest of physiology and for the whole science of Osteopathy.

As the lymph moves gradually from the lymph spaces to the venous circulation it is changed somewhat under the influence of the glands and lymphatic vessels. The lymph differs in the various organs in in which it arises, but the chief variation is that found in the lymph arising in connection with the alimentary canal called the chyle. When digestion is not going on the fluid formed is the normal lymph, during digestion it possesses certain peculiar properties. During the

As the lymph moves gradually from the lymph spaces to the venous circulation it is changed somewhat under the influence of the glands and lymphatic vessels. The lymph differs in the various organs in which it arises, but the chief variation is that found in the lymph arising in connection with the alimentary canal called the chyle. When digestion is not going on the fluid formed is the normal lymph, during digestion it possesses certain peculiar properties. During the digestive process, particularly if fatty substances have been taken in connection with a meal the lymph becomes milky. This fluid passes into the thoracic duct where it is mixed with the normal lymph, the milky character being retained on account of the predominance of the chyle. Chyle differs from ordinary lymph in the amount of fatty substances it contains, the amount of fat varying with the kind of food taken. The increase in the fatty substances is due largely to the neutral fats. The chyle is normally slightly alkaline with a specific gravity varying from 1018 to 1027. Examined microscopically it is found to contain large numbers of fat cells containing minute particles very similar to the white blood corpuscles. These are called lymph corpuscles. These cells appear in the chyle after its passing into the lymphatic vessels and glands. After removal from the duct chyle coagulates very much like the blood, consisting of a clot and a milky serum. If the lymph is taken from the duct just before passing out of the duct into the venous circulation it is of a slight reddish hue and on coagulation is more consistent and of a reddish color. This is probably due to the mixture of chyle with red corpuscles. In the chyle we find not only the cells but also very minute granules with characteristic amoeboid movements, these forming the characteristic constituents of the chyle. This minute granule division exists only in the lacteals. The chyle thus consists of lymph with the addition of a large proportion of these fat granules. The composition of the chyle is found to be in the human subject, in 100 parts, 90 p. c. of water, and about 10 p. c. of solid, of this solid matter there is about 7 p. c. of albumen, 1 p. c. of fat, 5 p. c. of salts and extractions and a small per cent of fibrin. The quantity of chyle daily formed cannot be accurately estimated. The amount of milky substance depends upon the fat. Even in the absence of fat, water, salts, sugar and peptones pass into the lymph spaces and the lacteals. These substances however probably are rapidly absorbed again in the bood vesssels so that probably only when mixed with fats do they pass into the lacteals of the villi and thence to the glands as chyle. Along with this chyle the real lymph exuded from the capillaries and not absorbed in the tissues passes into the ducts. It is estimated that a quantity of lymph or chyle equal to the whole volume of the blood passes through the large duct in 24 hours.

We have seen that there are thus two channels opened up through which the digestive products pass by absorption, the one through capillaries and the other through lacteals. In the first case they pass into the portal circulation by which they are conveyed to the liver. In the second case they pass to the lymphatic system and afterward fall into the general blood circulation. The peptones and the sugar pass readily through the capil-

laries of the villi into the portal system, whereas the fat after emulsification being unable to pass through the capillaries passes into the lacteals and thus finds its way into the lymphatic system.

2. Absorption by means of the other organs of the body. Absorption takes place in connection with (a) the skin (b) the serous surfaces (c) the pulmonary mucous membrane and (d) the other tissues generally. (a) The skin. Absorption by the skin takes place in connection with gases and to some extent fluids and semi-solids. By the absorption of gases like sulphuretted hydrogen through the skin after every other passage is closed an animal may be poisoned. In the case of liquids it seems almost impossible that fluids should be able to make their way through the epidermis and the fatty coatings of the outer surface. In addition to the strong coating the pressure is always very strong from the internal surface. This however does not prevent the demonstration of the passage of water and even fatty and oily matter through these surfaces particularly if associated with mechanical stimulation. These substances pass through or into the ducts of the oily layer upon the surface, being absorbed into the vessels found in connection with these glands. It is also possible for certain solid substances when in solution to be absorbed in this way, as in the case of saline substances. (b) Serous absorption. The serous substances are layer tissue or lymph spaces and their stomata communicate with the lymphatic vessels. During inflammatory stages there is an accumulation of fluid in connection with these serous surfaces, such as peritoneum, the fluid being absorbed. The absorption takes place rapidly in connection with the openings at the margins of the living cells. The fluid that is found in connection with these serous membranes is very much like the lymph. It is alkaline in reaction, containing about 4 or 5 p. c. of solid matter. (c) In the living membrane of the air vesicles the absorption of gases takes place very readily. Also fluids are absorbed, although not so freely.

For example, water passing through the air passages and cells may be absorbed without any detriment if not excessive in quantity. In the case of certain persons engaged in certain occupations small particles of foreign substances, e. g. steel filings, may be found in the lung tissues, having been breathed into the lungs and absorbed by or in connection with the delicate cells lining the surfaces of the air cells. (d) The tissues generally. From the blood nutrient matters are constantly passing out into the tissues and the amount of this matter is always in excess of the tissue requirements. In addition the injection of solutions underneath the skin brings these solutions into close relation with the connective tissue, these solutions being absorbed and passed into the system. This fact lies at the basis of the method of subcutaneous injection of medicinal remedies. In addition the constant activity of the tissue corpuscles leads to the formation of waste matters and these together with the excess of nutrient matters lie in the tissue spaces from which they are carried off, partly by the blood vessels and partly by a special set of vessels communicating with the tissue spaces, the lymphatics being carried into the lymphatic circulation.

NUTRITION PROPER:—In connection

with the nutritive process there are certain interchanges taking place between the blood and the tissues which must be considered. The capillary system brings the blood into close and direct relation with the body tissues so that these tissues are constantly supplied with the nutrient elements from the blood. In tissues that are very active and in the delicate tissues of the brain the capillary arrangement is so minute that each small portion is abundantly supplied with a fresh and freely flowing blood. In the cartilages of the body on the other hand where the vital processes are slow the capillary system is less rich and minute, the nourishment taking place largely by the oozing of the fluid through the spaces between the fibres. In all human tissues therefore there is a constant process of supplying nutriment, the matters being absorbed from the blood, the matters being transformed into the same substance as the tissues themselves or by a process of division may be divided into simple elements. We have seen that the food substances in the forms of peptones, sugar and fats with various salts pass into the blood and later we will find that various substances, urea, $CO^2$, salts are ejected from the blood by the excretory systems. It is evident that somewhere in the body active chemical processes are going on as a result of which elements that enter into the body in certain combinations are expelled from it in much simpler combinations, intermediate changes taking place which are called the metabolic phenomena of the body. For example, in muscular activity certain chemical changes take place resulting in the change of the protoplasmic substance producing certain simple chemical substances. This condition implies exhaustion to be compensated for by fresh supplies furnished to the tissues from the blood. These changes are of a very delicate character and while they are largely processes of oxidation and fermentation they are as yet very indistinctly understood. Claude Bernard speaks of the blood as the internal medium of all the nutritive changes. The blood is perpetually changing, giving and reciving new substances from the tissues involving all the organs of alimentation, secretion and excretion as well as the tissues themselves. In passing through the tissues the blood carries oxygen and other nutrient matters which are given up to the tissues for repair. Each tissue receives what is best for its nutriment in this way. This selection of appropriate substance by each tissue is called the selective affinity of the tissues. These changes take place according to the physical laws that regulate diffusion and the movements of fluids through tissues and membranes depending upon the circulation of the blood, the blood pressure. The nutrient substances of the blood pass out from the capillaries, bathing the various tissues, the corpuscles of which select the materials they require taking them up and conveying them into their own substance. This is assimilation or nutrition. In some cases the corpuscles directly or indirectly form materials other than their own substance, these materials being of use in various ways to the other corpuscles of the body. This is an important element in the phenomena of secretion. The formation of ptylin, pepsin, fat, glycogen are examples. Oxygen as well as nutrient matters pass into the tissues from the capillaries and combining with

some materials from the tissue elements produce chemical changes which lead to liberation of energy in the various forms of heat, animal movements, etc. and to the formation of waste matters. In the metabolic phenoma which takes place in the animal body therefore there is constantly going on a process of upbuilding or anabolism according to which changes take place resulting in the transformation of dead matter into the elements of the living organism. At the same time there is a constant process of breaking down or katabolism according to which the transformation takes place from complex chemical combinations to simpler elementary substances.

ANABOLISM: The albuminous elements of the body are built up entirely from the albuminate proximate principles of the food. The albuminous elements of food are converted during the digestive process into peptones and these peptones become albumen in the blood. The fat of the body is formed partly from the fatty substances which enter the body in the form of food and partly from the proteid constituents of the food. Hence fat may be formed in the body although all fatty substances are excluded from the food. Leibig thought that the carbohydrates were converted into fat, but this is only true to the extent that the carbohydrates act in the dissociation of the albuminates to form fat. The carbohydrates play an important part in the formation of fat, combining with oxygen they prevent the oxidation of fat or of substances yielding fat which therefore accumulate in the body. A large proportion of the fat is formed from the albumen. It is found that when the albuminous tissue of the dead body is placed under the action of water adipose is formed. If this fat in the body passes beyond the normal, obesity results. In order to prevent this it is necessary to prevent the use of fatty food, and the muscles should be exercised so as to oxidize freely the foods.

KATABOLISM:—Katabolic changes are carried on by the free presence of oxygen. The breaking down of the nitrogious matter yields by a series of steps nitrogenous waste in the form of kreatin, uric acid, urea. But from the carbon and hydroygen of the nitrogenous matter there are formed by the combination with oxygen, non-nitrogenous waste products, water and $CO_2$. The oxidation of the non-nitrogenons or of the carbonaceons materials of the body yield the non-nitrogenous waste products. Hence while the nitrogenous waste products which are eliminated from the body can be derived only from the albuminous food elements, the non-nitrogenous matters are produced by chemical changes taking place in connection with the carbonaceons and nitrogenous elements of foods. The first step in the process is the setting free of oxygen from the oxyhaemogoblin. When liberated the oxygen combines with certain of the elements found in the tissues resulting in the production of a number of chemical compounds, resulting from this combination we find the liberation of energy in the form of animal heat and movement.

In order to the proper nutrition of the body in connection with metabolism, three things are necessary:

1. Healthy blood and its proper distribution. If the circulation of the blood be stopped in a limb, organ, or part of the body, that part of the body becomes

enfeebled. If the blood supply is quickly cut off the limb or organ becomes mortified while there is sufficient serous exudation; if the supply of blood is cut off gradually the exudation ceases and the limb becomes dry as in the senile gangrene of the extremities in aged people. In order to prevent this the proper nourishment of the body must take place, because only in this way can the blood be kept in a normal, healthy condition. In the case of poisoned blood the system makes the effort to free itself of the toxin. In the case of fevers there is always an effort on the part of the excretory system to free the blood from these noxious elements through the skin and the urine. The fact is plainly evident in what are called the changes of life in which the change of a high organ affects the entire bodily system, changing the form of the body and giving to the body the characteristic features which mark the adult from the period of youth. So marked is this nutritive influence that the bodily nutrition may be entirely altered. Thus under the influence of vaccine the character of certain tissues may be so altered as to produce immunity from the toxic influence of a certain virus. This condition, however, is limited by time, because the organ or tissue so altered tends to return to its original condition. This forms the basis of the necessity for revaccination as a means of rendering the system immune against the action of virus. This same process goes on in the bodily system as a whole. There is a constant molecular change according to which the atoms of the body are being renewed and destroyed alternately so that one particle after another is removed to be replaced by new particles. In this way the tissues and organs of the body are constantly changing, but the change is a slow one.

2. Healthy tissue and its proper nourishment. This means that the tissue must be prevented from falling into a morbid condition and this represents the border line between physiology and pathology. If certain changes are introduced into the nutritive process, either suspending certain necessary changes or producing new changes destructive of the tissue then an unhealthy condition ensues. Even however, in pathological conditions there is a tendency to return to the normal condition. This forms the basis of the osteopathic idea that nature is sufficient to restore the healthful condition if the active metabolism of the body is rendered efficient, the body itself being nature's store-house of energy and restorative capacity.

3 Healthy nervous activity. We have already seen the close relation of the nervous system to the tissues and organs of the body. If a motor nerve is divided the muscle supplied by it will degenerate. If a nerve supplying a blood vessel or a mucous membrane be divided then the result is the degeneration of the affected part. In the case of paralysis the extremities waste unless there is some means of restoring the stimulation supplied by the nervous connection. Thus the entire bodily system depends upon the healthful nervous stimulation representing the trophic influence of the nerves, the nerve centers and the general nervous system. Psychic influences are most important from this standpoint. The mental conditions affect almost all, if not all, the organs of the body. The emotions affect bodily nutrition. Nutrition

is promoted by an easy and contented disposition and retarded by melancholic or anxious moods. The same thing is true of diseases and recovering from diseased conditions.

Closely connected with nutrition and nutritive changes is growth. This is manifested either in development of certain organs or in the development of the body as a whole. If the organ is unduly increased in size it is said to be hypertrophied; if the growth is suspended and the part is wasted from lack of nutrition, it is said to be atrophied. In the case of the entire bodily system, if the anabolism exceeds the katabolism, we have the condition represented by growing youth, whereas in the reverse case we have the senile stage. In the case of normal growth, we may find either the development if existing, but hitherto undeveloped, tissues or organs or the continuous increase of tissues or organs in active development. These two conditions represent the continuous development of the bodily organs as well as the development of special organs like the organs of reproduction. All of the influences already mentioned assist in this development.

Glycogenesis:—A large proportion of the food under the process of absorption passes into the liver before it reaches the general circulation. There are therefore important metabolic changes that take place in connection with the liver. The liver performs various functions. We have already discussed (1) the formation of bile. In addition there is (2) the conversion of certain substances, e. g., kretin and leucin into urea. (3) The breaking down of the red blood corpuscles, the coloring matter being utilized in the formation of bilirubin, (4) the formation of fat and (5) the formation of glycogen. The formation of glycogen is closely connected with the nutritive processes and marks the change taking place in connection with the different tissues. The discovery of glycogen formation was made by Claude Bernard when he found after death in the liver a quantity of sugar. In later years he investigated the subject proving that in life glycogen is formed in the liver and that under in the influence of a diastatic ferment the glycogen freely changes into sugar. In studying digestion and absorption we found that a quantity of sugar is carried as a result of these two processes by the portal system from the alimentary canal to the liver. If an animal be killed it is found that after a short time the blood in the hepatic veins, that is the blood which has passed through the liver, contains much more sugar than the blood in the veins, that is the blood that has not yet circulated through the liver. If the liver of a freshly killed animal, rapidly taken from the body, is cut in pieces and thrown into a vessel containing boiling water, the infusion contains little or no sugar. If however the liver be kept for a short time at a moderate temperature of 15.5° C. and then cut in pieces and thrown into boiling water the infusion will be found to contain a quantity of sugar, the amount of grape sugar being proportional to the length of time the liver is kept pefore being put into boiling water. There goes on then in the liver a process at least after death which results in the formation of grape sugar. What is the source of this glycogen?

If the opalescent, sugarless infusion

made from the liver immediately after death be treated with saliva ferment or any other ferment which has the power of converting starch into sugar, the infusion is found to become clear and to contain a considerable quantity of sugar. The source of this sugar is evidently some starchy body. When this opalescent infusion is treated with alcohol, a white amorphous powder is obtained. It has the composition of $C_6 H_5O_{10}$, is a white carbohydrate and may be rapidly converted into sugar by the action of dilute mineral acids. It is called glycogen and by some has been called Bernardin after its discoverer. This substance is evidently present in the liver, and probably by the action of some ferment becomes converted into sugar after death. The amount of glycogen varies in different animals. It exists in largest quantities a few hours after a full meal. It is lessened by fasting and it may disappear altogether by a prolonged fasting. That it is one of the life substances is evident from the fact that it disappears after death, being converted into grape sugar. If an animal is starved the glycogen present in the liver is gradually diminished in amount and through time it will disappear entirely. When a diet of carbohydrates is used an abundance of glycogen is found in the liver. If carbohydrates are withdrawn from the food and the animal be fed on proteids alone there is still found some glycogen. The amount of glycogen is influenced by the character of the food. The carbohydrates are transformed into maltose and the maltose passes into the portal circulation. If glucose is injected into the portal vein it is found that the glycogen formation is increased. The formation of glycogen also is increased by the use of food rich in starch, grape sugar, or any other kind of sugar. Even the albumin in the liver may be divided into a nitrogenous and a non-nitrogenous element, the latter becoming glycogen. Fats do not influence the amount of liver glycogen. It is evident that the chief source of glycogen is the carbohydrate matter taken as food, and this as we have seen, reaches the liver in the form of grape sugar. In this way the very soluble carbohydrate substances are converted into the less soluble and stored up in the liver cells for the use of the tissues of the body when no fresh nutriment can be derived from the alimentary canal. The glycogen becomes transformed into glucose under the influence of a ferment found in the liver, the conversion being arrested if the liver is placed in a temperature at or below 100 degrees C. or at or below 0 C., the extremes of heat and cold coagulating the ferment.

Glycerine extracts from the liver transform starch into sugar, the glycerine extracts of some other organs having at times the same effect. The glycerine extract of muscle has always this effect. The existence of sugar in the blood of patients subject to diabetes has been long known, but it is only recently that the relation to glycogen has been understood. The amount of sugar depends upon the nature of the food. When the amount is largely increased the kidneys separate it from the food and the condition is known as diabetes. a pathological condition in which a large quantity of sugar is found in the urine, due as we have said to the presence of a large proportion of it in the blood.

If the medulla of a properly fed rabbit

be punctured in the region of the vaso-motor center, it will be found in the course of an hour or two that the urine has a considerably increased quantity of sugar. The more rich the liver is in glycogen, in other words if the animal is well fed, the results will be more marked. If, on the other hand, the animal is starved the urine will be found to contain no sugar, or almost none. The puncture in the medulla causes the profuse discharge of the sugar from the liver until it becomes exhausted, for the urine will continue to exhibit marked increase in the proportion of sugar until a maximum is reached after which the urine will be normal. It was formerly supposed that the sugar was completely oxidized in the lungs, on account of the oxidizable nature of the glucose, particularly in the alkaline blood. This, however, is proved erroneous by the discovery of the fact that the amount of sugar in the blood at the left side of the heart is not smaller than that found in the blood on the right side of the heart. In addition to this, sugar is found in the blood in connection with all the body tissues, particularly in the muscles. Muscle also contains glycogen even after being deprived of food, the muscular action of the tissues using up the glycogen not only as found in the tissues, but also as stored in the liver. The glycogen converted into sugar is first used up by the muscles and used by the muscles in tissue-building.

Under the influence of curare diabetes may be induced, resulting in a paralysis of the muscles of voluntary activity, on account of the fact that the inactive muscles do not use up the sugar, the sugar accumulating in the blood and being excreted in the urine. This, however, is perhaps better explained on the basis of paralysis of the vaso-motor centre. While there is no doubt that after death the blood if made to circulate through the liver contains more sugar in the hepatic vein than in the portal vein, it is not settled as to whether the same condition exists during life. Different observers have given different results. Those who hold that no more sugar is present during life in the blood of the hepatic vein than in the blood of the portal vein regard the glycogen as one of the stages of a process which consists in the conversion of carbohydrates and perhaps even of proteids by the liver into fats. Almost all the evidence in favor of this idea is the fact that oil globules, sometimes in great abundance, are found in the hepatic cells. The formation and presence of glycogen in the liver are according to this view to be regarded merely as a step towards the formation of another substance, namely the fat. The theory opposed to this is that the glycogen in the liver is a store of carbohydrate matter which can by the conversion of glycogen into sugar, be drawn upon by the economy of the system when digestion is not going on; that is, when no carbohydrates are being furnished to the blood from the alimentary canal. The sugar and starchy substances of the food which result from the process of digestion and absorption pass into the blood of the alimentary tract as grape sugar and as such is conveyed to the liver. Part of this grape sugar passes at once into the circulation supplying the immediate necessities of the bodily system, the excess being stored in the liver, dehydrated and stored as glycogen. When food is not

supplied to the alimentary canal there is no carbohydrate matter furnished to the blood and it is then that the stock of glycogen stored in the liver is drawn upon. In this way a regular supply of carbohydrates is furnished to the body system. In favor of this idea is the fact that the amount of sugar in the blood is constant, remaining almost the same when food is being taken in as the intervals between meals. It would seem then that the function of glycogen in the liver is for the purpose of supplying a stock to be converted into sugar and to pass into the blood, the question arises, what is the function of this sugar? It was at one time supposed that the sugar furnished to the blood by the liver was oxidized in the passage of the blood through the lungs. This, however, as we stated above is incorrect. Hence the theory that when it reaches the general circulation it is distributed to the tissues of the body, especially to the muscles, seems to be generally accepted. In this way there are furnished to the muscles the necessary materials required for muscle contraction, so as to maintain the contractility of muscle. It is supposed by some that the muscle really performs the same function as the liver namely, withdrawing sugar from the blood and converting it into glycogen, the muscle forming in itself a small storehouse of deposited carbohydrates which can be drawn upon according to the requirements of the muscles. If the muscle becomes tetanized then the amount of glycogen is diminished. Although we have proof of the existence of a ferment in connection with the liver after death, this does not prove that such a ferment exists during life any more than fire in shed blood would prove the existence of the fibrin ferment in the living blood. Aside from the question of the existence of the ferment there still remains the difficulty of explaining how in the presence of such a ferment glycogen could be stored up in the liver and why that ferment appears to have such a strong effect immediately after death. From the fact that the puncture of the vaso-motor region of the medulla produces paralysis of the hepatic vessels, it has been concluded that the increased flow of arterial blood through the liver which results in the formation of sugar or its appearance in the urine and that ferment which converts the glycogen into sugar is conveyed to the liver by the arterial blood. The fact apparent that the presence of a large proportion of arterial blood in the liver increases the transformation of glycogen into sugar. It has been found also that temporary diabetes may result from an injury to the cerebral lobes, to the cerebellum, to the white cords outside the corpora albicantia, to the pons varolii, to the middle parts connecting the cerebellum and the brain above. The vaso motor nerve to the liver passes from the center in the medulla along the spinal cord passing into the sympathetic through the splanchnics into the liver. In leaving the spinal cord they pass along the vertrbral artery passing thence to the lower cervical ganglion; from this ganglion they proceed by division around the subclavian artery constituting the annulus of Vicusslus proceeding thence to the first dorsal ganglion and through the sympathetics and the semilunar ganglion to the hepatic vessels of the liver. If a division is made of any of these nerve connections, liver paralysis en-

sues, followed by dilatation of the blood vessels and the increased production of sugar. Cyon has pointed out that for the increased formation of sugar it is necessary that there be an increase in the blood flow. This increased blood flow may be effected (1) either by the direct paralysis of the vaso-motor center or (2) the inhibitory action of the sensory nerves upon the vaso-motor centers. If the vagus is divided and the cephalic end be subjected to stimulation the liver increases in activity on account of the increased blood flow through it. In this case the vagus exercises an inhibitory action upon the vaso motor center. (3) The same effect may be produced reflexly by stimulation of the pneumogastric in its terminal branches in the liver or the lungs, in the main trunk of the pneumogastric or at its roots in the medulla.

Glycogen is found in other portions of the body besides the liver. The skeletal muscles particularly manifest the presence of glycogen so much so that it becomes an almost invariable element in connection with muscle tissue. The amount varies in different muscles and also in different animals. It increases when the nervous connection is cut off from the muscle, and is lessened passing into dextrose on the passage of the muscle into the rigor mortis. It is not however a necessary constituent of muscle in the regular muscular metabolism, because muscles possess the contractility characteristic of muscles even without glycogen. It is found then in embryonic life the muscle is very abundantly supplied with glycogen, the glycogen gradually being diminished as the process of striation proceeds. In this case the large proportion of glycogen is stored in the muscle, so as to accelerate the rapid embryonic changes from the simple cellular protoplasm to the striated muscle. It is this fact that has helped to formulate the conclusion that the same function is discharged in the adult life, the carbohydrate matter so stored up as to be immediately at hand as available material in the muscular metabolism. Glycogen is also freely found in connection with the placenta in which it is found in connection with the epithelial cells that mark the separation of the foetus from the mother. In this case it discharges the same function providing a store of carbohyrate material for the nourishment and upbuilding of the foetus. In the metabolism therefore of the body from its earliest stages in the foetal life during the entire period of existence glycogen plays a most important part in connection with body development.

SECRETION:—This term is applied to the fluid products of glands. The term is used to desiginate a number of structures that differ in organization. A gland consists of a structure composed of gland cells secreting a fluid that is discharged upon a mucous surface or in connection with the closed surfaces in connection with the blood and the lymph. Secretions are either external or internal, the external referring to secretions discharged upon a free epithelial surface like the skin or the mucous lining, the internal being found in connection with the liver, pancreas, etc. In the case of external secretion it always takes place upon the free surface of epithelium the other side of the membrane being freely supplied with blood and lymph capillaries. The secretion always takes place in connection with the blood. Wherever

we have the membrane pouched or formed into sacs we have the primary gland. In the case of the compound gland we have the complexity of the involutions either in the common tubular or saccular form. In these compound glands it is only in the terminal parts that secretion takes place, these terminals being the alveoli, the communicating parts being called the ducts. The gland secretions are as different as the structures in which the secretions take place. In general these secretions are fluid or semi-fluid, being composed of water, salts and other organic substances. The organic element differ in the various glands representing the elements which are peculiar to the gland. In other cases the organic elements are found in the blood the gland simply separating the elements from the blood so as to be eliminated, as the urea of urine. These last are the excretions of the body, excretion being the process of the elimination of waste matters from the body. Formerly it was believed by physiologists that secretion was accomplished by filtration diffusion and inhibition. In modern times emphasis is laid upon the living membrane, the gland itself being used in the process of secretion, the epithelial cells being active in the secretory process. This is evident from the fact that an examination under the microscope the secretion is found to contain portions of the cellular substance, in some cases the cells being broken down to form the secretion. The substance of the gland cells passes into the secretion in this way and represents the metabolic process of the cell substance. The variations in the secretions are easily explained on this basis as depending upon the metabolism of the different gland cells. In addition the existence of nerves connected with these gland cells, the stimulation of which produces secretion is a confirmatory view of this theory. Cha ges of temperature in the gland are also noticeable in connection with the formation of the secretion indicating the existence of metabolic processes of heat changes marking the activity of the glands. Although the glandular structure is favorable to the processes of osmosis this does not seem sufficient to account for the secretion of salts and other substances. In this case the cells in connection with which are found two fibers, one regulating the production of the organic and the other the inorganic elements, play a very important part as these two fibers terminate around the cells. How the action takes place it is impossible to state. It is sufficient to indicate the fact that some cell metabolism takes place under the influence of nerve impulses conveyed to the cells by the nerve fibers. Heidenhain distinguished two kinds of glands, the mucous and the serous this difference being made on the basis of the physiological structure of the glands themselves and also upon the nature of the secretion.

The secretion of the serous glands is limpid, containing a large proportion of water together with a small quantity of albumen, salts and ferments; the secretion of the mucous glands is viscous on account of the amount of mucin present in the fluid. The proteid gland in the human subject is an example of the mucous gland. In the serous glands the cells are small and abundantly filled with granular material. In the mucous glands cells are larger and freer from granular

matter. The small goblet cells in the intestinal epithelium are examples of the mucous cells.

1. The salivary glands in the human subject are three fold—the proteid, the sublingual and the submaxillary.

Besides these we find a number of small glands embedded in the mucous lining of the mouth and tongue. These glandular secretions form the saliva. The parotid gland has nerve connections from the fibres originating in the glosso-pharyngeal, passing into the tympanic nerve and the ganglion in the oval foramen supplying the ear. From this ganglion they pass through the inferior maxillary division of the fifth cranial to the parotid gland. The cervical sympathetic also sends branch fibres into the blood vessels of the parotid gland. The submaxillary and the sub-lingual gland receive their nerve connections from the facial nerve through the chorda tympani passing through the sub-maxillary ganglion. Heidenhain believes that the secretion is determined by two sets of fibres, one regulating the secretion of organic matter and the other regulating the secretion of salts and water, the latter set of fibres being called secretory fibres and the former trophic fibres. These trophic fibres act in connection with certain metabolic changes in the cell. In the case of the cerebral and sympathetic nerve branches, the former contain the secretory fibres and the latter the trophic fibres or at least prevailingly so. The trophic fibres act by setting up metabolte processes in the cells resulting in the formation of certain substances like mucin. These processes represent the breaking up of complex matters and the formation of simpler substances found in the secretions. Side by side with this katabolism we find anabolic changes forming new materials from the blood supplies furnished to the cells. The action of the secretory fibres is obscure, although it is supposed that the flow of water is regulated by the gland activity, this gland attracting the water to it from the blood, the water being absorbed during the resting condition of the gland from the membrane which collects its fluid from the lymph, the lymph in turn being supplied by the blood. By the action of the secretory fibres the process of filtration is materially assisted, the water passing from the cell into the lumen of the tubule.

2. The pancreas in the human subject is found behind the stomach in the abdominal cavity. It is found to be a long, narrow gland, its upper end being in contact with the duodenum and its lower end resting upon the spleen.

The pancreas is one of the compound tubular glands, alveolor cells being serous, the outer part of the cell being composed of non granular substance, the inner part towards the cavity being granular. In addition to the regular cells there are also a number of small and clear cells irregularly shaped, supposed by some to be imperfect secretory cells. The tuburcular cavity of the cell is continuous with the capillaries which lie between the cells, the capillaries branching out into the cell substance. There are distinct secretory fibres just as in the case of the salivary glands. The stimulation of either the sympathetic or the pneumogastric increases the pancreatic flow after a period of latent rest. The same distinction of fibres is found in connection with the secretion, the secretory

fibres predominating in the pneumogastric and the trophic fibres in the sympathetic.

3. Stomach Glands:—The gastric glands are simple tubular glands, these possessing no symptoms of ducts such as are found in the compound glands. The pyloric glands have but one kind of secreting cell while the fundic glands have two different kinds of cells. These gland cells are concerned in the formation of the ferment of the gastric secretion. The cells are of two kinds in the fundic glands, the principal cells and the border or marginal cells, the latter being regarded by some as imperfect principal cells. This, however, is a mistaken opinion as these marginal cells have a specific function in connection with the formation of the secretion.

4. The liver is a compound tubular gland, the hepatic cells representing the secretory cells, the bile ducts carrying off the bile. The liver cells also form glycogen and urea. The liver is concerned in the formation of both the internal and the external secretions.

5. The Kidneys:—The kidney is a compound tubular gland. It consists of a secreting part and a collecting part. In the secreting part the epithelial lining differs very much in different portions. The solid part consists of a cortical and medullary part, the medullary part consisting of conically shaped malpighian bodies, the apex of these bodies opening into the sinus. The cortical portion is of a bright crimson hue. The secretion of urine takes place in the cortical part from which it is carried by the medullary part to the sinus from whence it passes through the ureter into the bladder. The kidneys are composed of a number of small glands closely bound together. The tubules pass almost straight through the medullary part but are very much convoluted in the cortical portion. Every minute tubule starts in the cortical part as a small sac surrounding the malpighian bodies. This sac is narrowed at the neck and the tubule forming it is very tortuous, passing into the medullary part and forming loops. In the loop there is a descending and an ascending portion, the latter part being spiral and forming the intercalary part or the tube, then forming the straight collecting tube. These small collecting tubes unite together passing to the papillae forming the papillary ducts. The blood vessels course freely in the interstitial connective tissue, the veins and arteries running freely through the medullary and cortical substance. The lymphatics are found in connection with the minute arteries and around the capsule, the vessels being accompanied by nerves, the nerve fibres passing through the basement membrane and terminating between the secretory cells. Two theories are held in regard to the secretion of the kidneys. One is that the secretion takes place simply by diffusion and filtration, the water being filtered through from the blood in the glomeruli, bearing along with it the urea and the salts. The dilution of this fluid takes place in the passage through the tortuous tubes by the process of diffusion in connection with the lymph that freely surrounds these tubes. The later theory is that water and salts are originated in the glomeruli, while urea arises in connection with the epithelial cells in the tortuous tubes through which the fluid passes in its passage through the kidneys. The secretion

thus takes place in connection with the glomeruli and also the cells of the tubules. It has been supposed that the water is produced by the process of filtration from the blood. The amount of water secreted depends upon the volume of blood circulating as well as upon the pressure of the blood. Heidenhain believes that the epithelial cells of the glomeruli are active in the process of water secretion, the formation of the water depending upon the physiological condition of these cells, the quantity of urine secreted depending more upon quantiy of blood circulating than upon the pressure of the blood.

6. The Sebaceous Glands are found on the superficial surface of the body, sometimes associated with hairs and sometimes not. The cells of these glands are arranged in layers, those lying nearest the cavity being filled with fat and being destroyed in the formation of the secretion. By the formation of new cells around the basement membrane the secretion becomes continous. The secretion or sebrum is an oily substance containing fat and soap, cholesterin and albumin, the secretion varying in character in the different glands in which its formation takes place. This sebum physiologically furnishes a protection to the hair and the epidermis. It provides lubrication to the skin and also the hair preventing the hair from becoming hard and brittle. In addition it furnishes protection against the rapid loss of heat from the animal body by evaporation, maintaining normally the epidermal character of the skin. Sweat is also a secretion in connection with the sweat glands of the outer surface of the body. These glands are found over all the external surfaec, particularly in the hands and feet. In the human subject they are simple tube glands, the ends of which contain the secretory cells, these cells being knotted upon one another to enlarge the surface of the sweat glands. The secretion varies with changes of temperature and also with the mental and physical condition of the subject. The sweat nerves are believed to be in the human subject secretory fibres, the secretion being the direct result of the nervous action upon the sweat gland cells. The terminal fibres are brought into close contact with these epithelial cells so that as a result of stimulation of various kinds the production of sweat may take place. An increased external temperature affects the sweat glands through the nervous system the temperature affecting the sensory cutaneous nerves and reflexly producing stimulation of the fibers of the sweat glands. It is not known where these sweat gland centers are, although the great center is supposed to be located in the medulla.

7. The Mammary Glands.—These glands are like the sweat glands, consisting of small divisions or cells, richly stored with albumin and fat. The cells of which they are composed consist of single epithelial layers. They are said to have originated from primitive skin glands without any mamma, these smaller primitive glands being united together to form larger ones, an opening arising in the skin localized in the nipple. In the human subject they are normally two in number and are localized in the thoracic area. The mammary ducts are not united into a single duct but are grouped together as separate glands with openings centered in the nipple. These

glandular cells are imperfectly formed unless during pregnancy when the cells multiply by a kind of cell generis during the period of lactation providing for an accumulation of the milk. The fluid secreted consists of a plasma and a great number of globlets which float in the plasma. These globlets consist of the milk fat, especially the neutral fats, olein, palmitine and stearin together with traces of the fatty acids, lecithin, cholesterin and the milk pigment. The milk plasma consists of water holding in solution, proteids, carbohydrates and salts. Among the proteids we find casein, lacto-albumin and lacto-globulin. The principal carbohydrate is the lactose.

A muscle proteid is also found in the muscleo-glyco-proteid. Traces of urea, creatin are also found in the plasma together with the citrate of calcium. This secretion takes place in connection with the epithelial cells as there are matters found in connection with the milk not found in the blood or lymph. During the resting condition the gland manifests in its vesicles a condition in which flattened cells appear with a single neucleus and with few fat granules. After the lactation commences the cells enlarge, the neucleus is divided and each cell is found with two neuclei. The fatty matter and the granules pass through a process of change, the cell itself being elongated and there being discharged from the cell end, the discharge and the disintegrated part of the cell being passed into the secretion. Part of this forms the fat-globules in the milk and part of it forms the constituent elements of the secretory fluid. Sometimes only part of the cell becomes disintegrated, sometimes the entire cell is dissolved. When the entire cell is dissolved the place is supplied by a process of karyokinesis. In the first milk secreted there is found peculiar cholostral granules. Heidenhain accounted for these by certain rounded epithelial cells which in the process of development develope fat-cell which are thrown into the gland, and others regard them as due to the dissolution of cells of connective tissue which degenerate and are discharged in the gland during its earliest stages of activity. It is supposed that mammary secretion is under control of the nervous system. It has been found that strong psychic influences have destroyed or suspended the milk secretion. The external spermatic by some of its branches furnishes vaso-motor fibers to the glandular blood vessels indirectly influencing the milk secretion by the influence exerted upon the blood flow in the gland. It has been found that the stimulation of the sensory fibers lessens the milk secretion. If the mammary glands are severed from all connection with the central nervous system then the stimulation of any of the afferant fibers has no effect upon the secretion. If the external spermatic be divided on the two sides then the secretion is lessened. The mammary gland must be subject to the control of the central nervous system, but whether this takes place through the vaso-motor fibers or through secreting fibers cannot be settled. It seems to be automatic in action, the relation between the mammary glands and the uterus depending upon the blood rather than upon nervous connection. The secretory cells are not formed until after the first pregnancy, the secretion beginning only after parturition. The first secretion is that of

cholostral fluid, differing in milk in the character of the cells which have passed through the stage of decomposition. After a few days the cholostorium gives place to milk which is secreted in the galactophoric ducts, the secretion continuing until the duct is filled when the formation of the secretion is inhibited.

INTERNAL SECRETIONS are formed within a gland and are passed from the gland either into the blood or the lymph. In every active tissue there is a waste which is carried into the blood and the lymph. The internal secretions however refer to those secretions which take place in definite glandular organs which are used either by the organ or for the metabolism of the entire body. These secretions are found in connection with what have been called the ductless glands. In connection with the liver there is a substance formed which passes into the blood that falls under this head, namely urea. It is the principal nitrogeneous waste of the proteid metabolism. It passes off from the body through the kidneys but it not formed in these glands. It seems to be formed in the liver in connection with certain substances that arise out of the proteid metabolism. The urea is secreted in the liver and from thence it is given off to the blood. In connection with the pancreas it has been found that there is also an internal secretion. The pancreas has been removed without any immediate fatal results. After the removal of the pancreas it was found that the urine passed a large excess of sacchrine matter. In this case it is found that this condition of glycosuria follows even when the carbohydrates are taken out of the food. The urine increase in quantity accompanied by a thirsty condition. If these conditions continue the animal becomes weakened and emaciated death ensuing in two or three weeks. Experiments have been made on animals which prove that the partial removal of the pancreas prevents the accumulation of sugar in the urine. From this it is concluded that there is a secretion in the pancreas which either consumes the sugar that is produced in the organs of the body or else prevents the sugar from being eliminated from the liver and the body tissues.

The THYROID BODIES are glands found in the human subject, joined together in front to the trachea. They consist of a number of closed cells of varying size each cell being covered with epithelium and filled with a shiny fluid. This fluid is a gluish liquid called colloid, the secretion of the cells of the thyroid, first secreted in the cells and then thrown out into the cavity of the body. It is believed that this fluid is finally discharged into the lymphatic system. The extirpation of the thyroids in animals is attended with fatal results, death being preceded by muscular twitchings which sometimes pass into spasms, and also by a condition of malnutrition, almost amounting to emaciation. In the lower animals fatal results have not always followed thyroidectomy, perhaps chiefly because of the existence of accessory thyroids which on the removal of the thyroid take their place. In the human subject the fatal results are much slower in appearing, being accompanied by anaemic conditions, muscular debility, loss of mental capacity and a characteristic subcutaneous swelling. If a small part of the thyroids are left then the fatal results do not follow. The thyroids therefore

have an important function in connection with the body metabolism. According to some their function is to absorb and take out of the blood certain noxious substances which would interfere with the metabolic processes. The removal of these bodies produces a condition it is said of auto-toxication. In proof of this it is claimed that the blood and urine of animals from which the thyroids are removed has a peculiar toxic influence if injected into other animals. According to others the thyroids secrete a fluid which when discharged exercises a potent influence upon metabolism especially the metabolism of the nervous system. In proof of this it is claimed that to inject thyroidal extracts produces good results. This substance formed in the glands reaches the blood through the lymphatic system after it has been secreted within the cells of the gland. Some have been successful in extracting from the gland a substance called thyroid which is found to contain a large quantity of iodine and which is found to have good results in cases of goitre and myxodema. This proves that the thyroid produces an iodine compound and it has been found that this compound consists of a combination with proteids. Recent experiments have indicated the presence of a number of such compounds all of which are found to be valuable in the body metabolism. The supra-renal capsules form another of these ductless glands. The complete extirpation of these bodies is followed by death, the fatal effect resulting more quickly than on the case of the removal of the thyroids. Following the removal we find muscular and mental exhaustion and a marked blood depression. These results correspond with the conditions in connection with Addison's disease in which case there is a supra-renal disturbance. It has been claimed that death results from the removal of the supra-renals on account of the presence in the body of a toxic substance which produces auto-toxication. Others have claimed that the supra-renals discharge an important function in connection with the muscles. Solution of the medullary part of the gland has been found to exert an influence upon the muscles of the heart and the skeletal muscles. In the case of the heart it was found that in the division of the pneumogastrics the heart's action became stronger, whereas muscular contraction became more protracted, the blood pressure being greatly increased. From this it is concluded that the secretion of the sura-renals is constantly of value to the muscles and other tissues of the body acting as a stimulant. In regard to the pituitary body it is claimed that fatal results follow its complete extirpation and that it follows the same course as death from thyroidectomy, indicatiug that they perform the same function or similar functions in the body metabolism. In connection with the reproductive glands Brown-Sequard has has made a number of experiments. Fresh testine injected into the blood has a wonderful tonic influence on the nervous system, especially in connection with the spinal centers, in case of neurasthemia and general debility. This is due to the presence of a substance in the secretion which passes into the blood. A substance entitled spermin extracted from the secretion has been found to materially assist the metabolic processes, not only having a tonic influence but also

diminishing bodily and mental fatigue and increasing the efficiency of the neuro-muscular mechanism of the body.

THE SPLEEN is an organ whose functions as yet are not distinctly understood. The spleen may be removed without any fatal results, the noticeable effects being that after the removal there is an enlargement of the lymphatic glands and the bone marrow together with an increase in the activity of the medulla. It has been found that one result of the removal of the spleen is the decrease in the number if red corpuscles. From this it has been inferred that the spleen has something to do in the formation of the red corpuscles. The spleen is known to increase in size during digestion and to remain for a time enlarged afterwards returning to its normal position. This is probably due to the action of vaso-dilator fibers and the relaxation of muscular contraction. The spleen also manifests slow rhythmic contractions and expansions and alterations in size corresponding with the variation of blood pressure and coincident with the respiratory movements. These alterations are determined by contraction and relaxation of the muscular fibers of the spleen and also the change in caliber of the arteries, both of these changes being regulated by the nervous system. In the spleen there is a special local circulation, the spleen being abundantly supplied with nerves which upon stimulation cause the decrease of the size of the spleen. In the spleen there is found a large proportion of iron. together with fats, fatty acids and nitrogenous extractives xanthin, uric acid, etc. The uric acid is always present. The existence of these substances seem to indicate that certain active changes take place in the spleen in connection with the metabolic processes of the body. During foetal life it is certainly a producer of red blood corpuscles. Uric acid is said to be produced in the spleen but whether it is formed in the spleen is not settled. If so then it must be formed in the spleen as well as in the lymphoid tissue generally. But nothing definite can be stated.

EXCRETION:—We have seen how the food passes through the digestive process and by absorption passes through the blood to the different tissues of the body. In passing through the blood and the tissues certain changes take place, the excess of fluid being carried as waste into the lymphatic system out through the lymph into the blood. These waste substances that find their way into the blood are not only excess but they represent dangerous elements if continuously accumulated in the blood. These substances that are eliminated are called excretions. Generally speaking these waste elements consist of urea, $CO_2$, salts and water. These waste matters are eliminated through five different channels, the lungs, the intestines, the liver, the skin and the kidneys. As we saw in connection with respiration the lungs excrete the $CO_2$, and also a quantity of aqueous vapor. In connection with the intestines we fonnd that in the form of faeces the undigested parts of food and the matters secreted in the intestines are excreted as faecal matters. There remain to be considered the two main excretory organs, the skin and the kidneys.

1. THE SKIN:—It is concerned in the functions of sensation, protection, respiration and also excretion. It has an important part to play in connection with

animal heat. The skin has two layers, the deep layer of connective tissue called the corium or dermis, and the superficial layer of epithelium called the epidermis. The corium consists of furrowed and cross furrowed areas. This corium consists of connective tissue interlaced with elastic fibres, the meshwork of tissues differing in the different layers, two of which are important, the papillary and the reticular, the latter or deeper layers presenting numbers of fat cells, underneath these being the subcutaneous layer in which fat cells are abundant. The epidermis consists of tessilated epithelium with at least two strata, the deep or soft stratum called the malpighian stratum and the dense or corny stratum. In thick epidermal regions as in the hand and foot there is a middle layer lying between the deep and dense layers. Connected with the skin are hairs consisting of a shaft, that part above the skin, the radix pili, the part passing into the skin sunk into the follicle and the bulb at the end of the root, with a tubular recess filled with tissue called the papillae. The sebaceous glands open into the follicle. In connection with the integument we find two glands (a) the sudoiferous or sweat glands. These are tubular glands, bell shaped at the end, being the secreting part situated in the subcutaneous tissue. The long straight duct passes with a slight winding course through the corium between the papillae running through the horny epidermis and opening on the surface. These glands are found all over the body except on the glans penis and on the inner surface of the preputium penis, being found most abundantly on the palms of the hands and the soles of the feet; being as many as 2500 to the square inch. (b), the sebaceous glands are simple or compound racemous glands. They are found in the corium and consist of a short duct opening into or in connection with tubes that open into the hair follicles. The secretion is a fatty matter mingled with the remnants of broken up cells. These glands are found all over the body except on the palms of the hands and the soles of the feet. Some of these glands not being connected with hair follicles as on the lips of the labii minora the glans penis and the preputium penis.

The horny layer of the epidermis acts as a surface of protection and also as a barrier against the absorption of poisonous substances. A limited quantity of water may be absorbed through the skin. Other substances particularly if mixed with fatty or oily substances especially in connection with mechanical rubbings pass through the skin into the subcutaneous lymphatics. The epidermis is the medium through which the nerves of ordinary sensation receive stimulation and it may be that the deep cells of the stratum mucosum are to be regarded as the terminal organs of these nerves although the actual termination of the nerve fibres in the cells have not yet been definitely made out. To a slight extent respiration takes place through the skin, about 10 grams of oxygen being absorbed, about the same amount of $CO_2$ being given off in the course of 24 hours. But the chief function of the skin is that with the glands, it presents a large surface through which excretion takes place. The chief substance excreted through the skin is water with a comparatively small quantity of salts and a small quantity of $CO_2$. In the human subject the perspi-

ration takes place largely on the forehead, in the palms of the hands, the soles of the feet and the armpit.

1. Sweat:—The sweat yielded by the sudoriferous glands is a watery fluid, transparent, with a peculiarly saline taste and a characteristic odor varying in different parts of the body. The sweat is in the human subject acid in reaction, it is alkaline when very abundant. This acidity is due to the sebaic acids arising from decomposition of the sebaceous matter found in connection with the sweat glands. The specific gravity is about 1004. On microscopic examination there are found oil globlets and crystals and sometimes, some epithelial epidermic cells. Normally perspiration contains 97.5 to 99 p. c. of water, and from 1 to 2.5 p. c. of solids. About 2-3 of the solid matter consists of organic matters and 1-3 of inorganic substances in the form of salts, sodium chloride constituting the large proportion. There are also found phosphates and a trace of iron oxide. Some traces of urea have been found but this normally is decomposed giving rise to ammonium salts. Small quantities of the volatile fatty acids are present giving rise to the sweat odor. Lactic acid is not present in a normal condition. There are also found the neutral fats and small traces of albumen. The amount of sweat varies in different animals. Anything that assists the blood supply to the skin tends to assist the sweat secretion and if the water evaporation is greater from the glands than normal the surface of the skin is covered over with a profuse perspiration. Secretion of sweat is produced by exercise, profuse drinking of water, hot baths, a high temperature and friction applied to the surface of the skin. Morphine and atrophine diminish or stop the flow of sweat whereas muscarin, strychnine, nicotine, and camphor increase the sweat flow. Mental condition of excitement either of excessive joy, anger or grief increase the secretion of sweat. There is a sympathy between the two excreting organs so that if the action of the kidneys is partially arrested as in certain abnormal conditions the skin will discharge the excretory functions more generally. It is estimated that about 900 c. c. of water is discharged by the skin in 24 hours in a normal adult or about .01 part of the body weight. The first sweat secretion is more rich in fatty acids and salts with less inorganic salts, the reverse being true when perspiration becomes free when the secretion becomes alkaline. Free perspiration lessens the the flow of urine and at least diminishes the quantity of urea found in the urine. Iodine, alcohol and ordoriferous elements may be discharged. The sweat secretion is dependent upon the blood pressure in the minute capillaries, the development of the gland cells and the nerve supply to these cells. After the secretion takes place the excretion is aided by the contraction of the smooth muscular fibres found between the cells and the membrana propria. Perspiration is more profuse on the right side than on the left. The innervation of the sweat glands depends upon the vaso-motor nerve, the dialators and the constrictors and the trophic and secreting fibers. Perspiration will not be produced by the simple effusion of blood to the surface of the skin. Pallor may be found along with profuse perspiration, in this case the vaso-constrictors and the secretory fibres being active.

There is no doubt that special secretory fibres are in existence. If the sciatic nerve is cut in the cat and stimulation be applied to the peripheral end, perspiration will be found freely in connection with the feet pads. A cat whose sciatic nerve was divided on one side when placed in a hot room was found to perspire freely in the three feet while the foot in which the sciatic nerve was divided did not sweat at all. These secretory fibres in the sciatic nerve originate from the spinal cord from the frontal roots of the spinal nerves from the 9th to the 13th dorsal vertebrae. Some have located in this spinal area, a spinal sweat center. The secretory nerves of the front limbs in the cat are found in the median and ulnar nerves arising from the spinal cord in the lower cervical region. The secretory fibres of the head and neck have been found in the cervical sympathetic in the facial nerve and the fifth cranial, arising from a brain center, possibly one of the cerebral centers as the mental states of excitement, emotion and pain produce influences affecting the sweat glands of the face and neck. The stimulation of the facial nerve has been found to produce perspiration on the cutaneous region supplied by this nerve and also on the opposite side. This seems to indicate reflex action in connection with the sweat centers. In what way this takes place is as yet unknown. If the perspiration is not very profuse and if the atmosphere around is dry the watery fluid in the sweat passes off quickly as vapor, this vaporous element being called insensible perspiration. If on the other hand perspiration is profuse or if the atmosphere is moist the sweat freely flows over the surface of the skin and it is called sensible perspiration. If the skin surface becomes covered with solid substances the skin will be coated so as to prevent the free action of sweat, the openings being closed. This constitutes one of the fundamental reasons why baths should be regularly taken by persons desiring to maintain normal health so as to keep the pores of the body open and to permit of the free and active exercise of the sweat glands.

2. The Excretions of the Sebaceous Glands:—The substance secreted is of an oily character, semi-fluid and of a characteristic odor. The fatty substances are formed by the epithelial cells of the glands. The sebaceous secretion consistsrof about 31 p. c. of water, 61 p. c. of albuminous matter and broken down cell substance, 5 p. c. of fatty matter and soaps, including olein, palmatine and sodium palmitate, with 1 or 1.5 p. c. of inorganic salts including the chlorides and phosphates. This includes the wax formed in connection with the ears and the secretion of the eyelids. The ear wax is said to contain fat cells and cholesterin crystals. The amount of oily matter secreted varies among animals according to the species and even among individuals.

3. Gaseous Excretions:—The skin from the standpoint of respiration is concerned in the exchange of gases. The capillary vessels in the outer layer of the corium contain oxygen and $CO_2$ and as the epidermis is the only separation between the gases and the atmosphere the exchanges take place upon the basis of the laws of diffusion the $CO_2$ being given off and oxygen being taken in to unite with the haemoglobin. By the enclosure

of the human body in a gas tight chamber it has been found that by shutting out the respiratory gases the quantity of $CO_2$ given off in a day amounts to from 6 to 8 grams. Similarly from 6 to 8 grams have been absorbed by the skin in a day in the human subject. It is estimated that $CO_2$ is given off by the skin to the extent of 1-150 and oxygen taken in to the extent of 1-140 of that given off and taken in in connection with the lungs. This indicates that the exchange by the excretory process of the skin is small as compared with the amount of gas required in respiration. The formation of sweat is influenced by the same circumstances that influence the formation of other excretions, namely, (1), The supply of blood; (2) the nervous impulses, and (3), the activity of the glandular epithelium. Hence where cutaneous vessels are dilated as when the surrounding atmosphere is warm the excretion of the skin is increased while under opposite conditions the perspiration is very scanty in amount. The effect of nervous influences, independently of the blood supply to the sweat glands, upon the formation of sweat has as in the case of the sub-maxillary gland been demonstrated by experiments on the lower animals. The phenomena of increased sweat under excitement, emotion, etc., is a well known example of this influence in connection with the higher centers. Similarly the cold sweats of phthisis in which pathological condition there is not an excessive but a defective blood supply to the cutaneous vessels.

The Kidneys:—The kidney consists of a cortical and medullary part, the medullary part being formed into the pyramids of malpighi opening into the sinus. The cortical portion is soft and of a dark color. The secretion takes place largely in the cortical part after which it passes through the medullary part into the sinus from which it passes into the the pelvic cavity of the ureter and thence into the bladder. In the kidney we find a large number of tubular glands closely connected, the tubes being very tortuous in the cortical portion and straight in the medullary portion. Each of the tubules originates in a small sac encompassing the malpighian bodies in the cortex, the tube running into the medullary part forming a loop and returning to the cortex, beccoming spiral and forming the intercalary tube and then straightening out into the collecting tube. These collecting tubes unite together forming large tubes which become ducts in the papillæ. These minute tubules vary in size at different points, the smaller tubes passing into the intercalary ducts and finally into the wide collecting tubes. These tubes lie in the midst of loose masses of interstitial connective tissue in the midst of which the minute blood vessels are found. The renal artery branches into the renal substance passing through the medullary part and passing up to the boundary line between the medulla and cortex, forming plexuses with the convex parts towards the cortex. Out of these convex arches arise the interlobular arteries which branch off into the lobules each glomerulus receiving one branch which is divided so as to form afferent and efferent vessels with capillaries branching off into the interlobular veins. These minute veins anastomose freely with the veins in the cortex. The renal lymphatics are found

in connnection with the capsules and the minute arteries in the renal substance, nerves accompanying the minute vessels but with connection as yet unknown.

The kidneys functionally are the organs through which the urine is drained off from the blood. Through them the main part of the nitrogenous waste of the body with a considerable quantity of water, some $CO_2$ and salts are excreted. The normal urine is a clear yellowish, slightly phosphorescent fluid with a peculiar odor and a saline taste. It is acid in reaction, the acidity being due to the presence of an acid phosphate of soda. The degree of acidity depends upon the diet. Thus with a vegetable diet the proportion of alkaline salts excreted in the urine is increased and that fluid becomes less acid or even alkaline in reaction. When the gastric juice is being secreted, as when food is taken into the stomach, the acidity of the urine is decreased. As digestion becomes more complete the urine becomes again distinctly acid. On exposure to the air for a time the urine becomes more markedly acid and urates or uric acid may be deposited but subsquently the reaction changes to alkaline the urea combining with elements of water to form carbonate of ammonium, under the influence of micro-organisms. A deposit is also thrown down the phosphates being precipitated partly as phosphates of lime, partly as the triple phosphate of magnesia and urate of ammonia. The urine temperature is normally about 39 ° C. After standing for some time there is a mucuos deposit, representing mucous corpuscles and sometimes flattened epithelial cells. Later this deposit will yield uric acid crystals and still later the urate of soda. Later the acidity lessens and then it becomes alkaline, fermentation setting in on account of the presence in it from the air of the micrococcus ureae, microscopic examination revealing the presence of bacteria. The mean specific gravity is 1020. The color of the urine varies both in health and disease. It may be pale, colorless or dark colored. In diabetes it is usually very pale, it may be milk colored on account of the presence of chyle, dark red from the presence of pigment or greenish from the presence of bile. Normal variation depends upon the varying quantities of the pigment urobilin which is the same as bilirubin. The urine consists of

1. Water. The solid matter in the urine consists of about 4 p. c.

2. In inorganic salts. Sodium chloride is the most abundant amounting to about 1 p. c. in normal conditions. Chloride of calcium, chloride of potasium, phosphate of lime and chloride of magnesium together with sulphates are also found in small quantities.

3. Gases. These gases consist of $CO_2$, N and O, altogether the O is present only in very minute traces. Carbonic acid is found loosely combined with the acid phosphate of soda.

4. Pigments. The pigments of the urine are not very satisfactorily known. The exact nature of the yellow coloring matter is uncertain. Urobilin which can be formed from bilirubin is sometimes present and also indican or indoloxyl sulphate of potasium, which is believed to be produced in the alimentary canal and which on oxidation yields various indigo pigments.

5. Nitrogen. The principal nitrogenous elements are urea and uric acid. Small quantities of substances related

to urea are also found, kreatinin, hypoxanthin. These nitrogenous matters result from changes in the proteid substances in connection with the body metabolism.

6. Non-Nitrogenous Elements: — Small quanities of various acids are found, oxalic acid, lactic acid, butyric acid and it is said that glucose in minute quantities is also normally present. A large quantity of water, salts and nitrogeneous substances is separated by the kidneys. If an animal is fed upon a flesh diet the urine is clear and acid very abundant in urea and the phosphates and uric acid. The nature of the diet very much alters the urine. In the case of a mixed diet the urine is intermediate. Of water excreted from the body about 40 per cent. is eliminated by the skin and lungs and 60 per cent. by the kidneys. If the diet is wholly or almost wholly animal flesh the amount of water excreted by the urinary system is increased to 70 per cent. If the quantity of urine is increased the amount of solid matter eliminated will also be increased, the urea being generally increased from 3 to 4 per cent. If the supply of water is cut off from the bodily system the amount of urine is diminished normally about 1-4 or 1-5. In the case of the use of drugs that are quickly dissolved the substance in solution may be found very shortly after being taken in the urine.

Urea:—The chief organic constituent of urine is urea. The average amount of urea secreted in 24 hours is about 30 grams. It is the principal nitrogenous waste excreted from the body. It contains about 46 per cent. of nitrogen. The quantity of urea excreted depends upon the food. When an animal is starved the amount excreted is lessened gradually diminishing until death takes place. The formation of urea takes place in the liver and as the blood in the renal vein has less urea than the blood in the renal artery it is said that no urea is formed in the kidneys. Containing as it does nitrogen it must be derived from proteid substance or rather from the albuminoid tissue elements or from the nitrogenous proximate principles of the food. The quantity of urea excreted is not influenced by muscular activity but is distinctly increased when a diet rich in albuminous materials is taken. Hence it is concluded (1) that muscle when actively working does not produce nitrogeneous waste and that therefore its contractile activity is not accompanied by oxidation of its own substance in the form of nitrogen but rather by the burning of certain carbonaceous materials that are deposited in the muscle substance. (2) A part of the proteid food material is in some way converted into urea. We have seen that the tripsin of the pancreatic juice converts some portions of the proteids in the food substances into leucin, tryosin, etc. When leucin and tryosin are introduced into the alimantary canal the amount of urea in the urine is increased, but no leucin appears in that fluid. There is therefore good ground for believing that the leucin formed by the pancreatic juice in the digestive process is at least one of the sources of the urea of the urine. If leucin is present in the alimantary canal it will doubtless be absorbed and carried to the liver in which the urea is found. This substance is not present in the muscular, nervous and glandular tissues of the body aside from the liver. This leads to the conclu-

sion that one of the functions of the liver and also of the spleen is to transform leucin, etc., into urea. This conclusion is strengthened by the fact that in acute atrophy of the liver, a diseased condition in which the activity of the hepatic cells is seriously interfered with, the urea of the urine is replaced by leucin and tryosin. We said that muscle does not by its contraction increase the excretion of nitrogenous waste. But the corpuscles which compose muscle as well as those found in nervous, grandular and other tissues are the centers of a constant metabolic process involving changes which imply the formation of certain waste products such as krentinin, xanthin, etc., which are to be regarded as resulting from the chemical changes connected with the existence and development of the corpuscles. These substances are more or less readily diffusible and will be carried off from the tissues by the blood ultimately reaching the kidneys. But the urine contains very little kreatinin and converted it into urea excreting it as such into the uriniferous tubules. It is now known, however that the extirpation of the kidney leads to the accumulation in the blood not of kreatinin but of urea. From this it is concluded that the formation of urea is not dependent upon or caused by the activity of the renal epithelium. As we have said there are reasons for believing that the liver is actively engaged in the formation of the urea from leucin. It is concluded from this by analogy that the liver also converts kreatinin into urea. If this be so then the urea of the urine has a double source being derived partly from the kreatinin formed by the ordinary chemical changes taking place in connection with muscle and other tissues and partly from the leucin resulting from tryptic digestion of the proteid food stuff. Both the kreatinin and the leucin according to this would be changed by the liver and possibly by the spleen into urea and the function of the renal epithelium is confined to gathering up the urea so formed from the blood and the excretion of it into the uriniferous tubules. If the urea and other forms of nitrogenous waste should fail to be separated from the blood as we find in certain renal diseases, their accumulation in the blood will lead to convulsions and other symptoms grouped under the term uraemia.

Liebig defends the theory of the derivation of urea from the muscles. Muscular activity he believed to depend upon nitrogenous substances either taken from the food or from the tissues. The food stuffs he regarded as either tissue forming or heat producing, the former being the albumen and the latter carbohydrates and fats. The albuminous matters he claimed were used in tissue upbuilding and in the production of muscular activity. The carbohydrates and fats by oxidation processes being converted into heat. Hence he concluded that in the dissociation of albumen in connection with the tissue urea was formed. Experiments of various physiologists have negatived this theory, the amount of urea found in the muscle being very small and muscular activity not tending to increase the amount of urea. The amount of carbonic acid is increased by muscular activity, the muscular energy being derived from non-nitrogenous food elements more largely than that derived from nitrogenous food elements. In addition to what we have said as to the formation of urea

in the liver it is found that in the case of phosphorous poisoning the amount of urea is greatly decreased and that by destroying the blood corpuscles and freeing haemoglobin the amount of urea is largely increased. Noel-Paton has shown that the bile secretion and the urea formation are directly related to each other. Therefore the chief source of urea formation is the destruction of the red blood corpuscles in the liver and in the spleen.

Uric Acid:—Next to urea the most important element in urine is the uric acid. About 5 grams per day chiefly in combination with kreatinin and xanthin are excreted. It is probably produced in the same way as urea as it is increased by a diet rich in albuminous material. It is sometimes regarded as an intermediate state in the metabolic changes of the proteids which immediately precede the urea. It has been suggested that on account of the close relation of uric acid to xanthin and hypoxanthin the uric acid is produced from these by oxidation. If uric acid accumulates in the system it may give rise to gout or when excessively found in the urine may form renal or vesical calculi.

The Aromatic Substances of Urine are absorbed from the small intestine and excreted through the kidneys. These arise from the decomposition taking place in albuminous materials in connection with the pancreatic juice.

Urobilin found in urine is derived from the hæmoglobin decomposition in the liver.

Indican is probably derived from indol which arises from the putrefaction taking place in the large intestine under the influence of a micro-organic ferment.

The saline matters depend upon salts in the food. The chloride of sodium is a necessary element in the urine excretion. If it is withdrawn from the food supply the amount excreted is diminished and a minmum quantity continues to be excreted till death results. Phosphates are derived from the food elements and also from the tissue metabolism. Sulphates arise from the albuminous decomposition.

Mechanism of the Excretion of Urine:—The kidney is a compound tubular gland the ultimate termination of the tubules, the glomeruli, being lined by a layer of single squamous epithelium, while the other parts of the glandular tracts, for example, the convoluted tubes have an epithelium which is more distinctly of a glandular character and which from the shape and appearance of its cells we should expect to be engaged in the separation of materials from the blood.

The blood reaches the kidneys through the renal arteries immediately from the arterial system, the branches of which pass into the substance of the kidney and by dividing ultimately form the afferent vessels to the glomeruli. In each glomerulus the afferent vessel breaks up into capillary loops which reuniting form the efferent vessel, this being of smaller calibre than the afferent. Hence the blood in the glomeruli is at a considerable pressure and the rate of flow is slow. Under the influence of this pressure water containing highly soluble and diffusible salts in solution filters through the walls of the capillary loops of the glomerulus and the epithelium covering the glomerulus into the Bowman's capsule. From thence it passes into the uriniferous tubule. The efferent vessel after leaving

the glomerulus breaks up into capillaries which are distributed over the surface of the convoluted tubules and it is believed that the large epithelial cells in these tubules extract from the blood in the capillaries certain substances, the nitrogenous matter and perhaps also pigments and excrete them into the uriniferous tubules. As it passes through the organs certain matters are lost which constitute the urine. This waste may take place by transudation from the blood or by active secretion of the epithelial cells or by both of these processes. The process of secretion is dependent upon blood pressure, increase in blood producing an increased secretion. If the renal circulation becomes too slow indicating a great fall in blood pressure the secretion is arrested. Severe loss of blood decreases the secretion, the increase of aortic pressure causing an increase and the decrease of aortic pressure a decrease of the secretion. Hence the process by which the urine is separated from the blood by the kidneys may be said to consist of two parts. (1) A filtration process in Bowman's capsule by which a large quantity of water with certain solid salts in solution is rapidly removed from the blood. (2) A true excretory process. The epithelium of the convoluted tubule by its vital activity separates nitrogenous and other matters with some water from the blood. The process of filtration must necessarily be dependent on and must largely be influenced by the blood pressure in the smaller arteries in the kidneys, for the flow of urine ceases when the pressure in the uriniferous tubules is greater than the pressure in the blood vessels, for example when the ureter is ligatured.

The rate of secretion depends upon the difference in pressure between the renal arteries and the urinary tubules By the increase of pressure in the kidney, the urine secretion is increased. The filtration grocess is not to be regarded as identical with ordinary filtration through dead materials, for the cells of the capillary walls and those of the epithelium covering the glomeruli undoubtedly exercise some influence in determining what substances shall pass through them. On the other hand the secretory process is only influenced in a secondary degree by blood pressure being dependent upon the activity of the cells lining the convoluted tubules and these cells as far as known are stimulated to their activity by various substances contained in the blood. An increase in the amount of water for example, by profuse drinking, increases the excretion of water by increases the blood pressure. The pressure theory of itself is insufficient to account for the secretion. While the blood is alkaline the urine in the human subject is acid. There is also a larger proportion of urea and salts in urine than in the blood. Certain of the substances found in urine are not found in the the blood as kreatinin. As the urine differs in its character from the blood it cannot simply be a transudation from the blood. If the renal vein be compressed or ligatured the pressure in the glomeruli will be increased but the amount of urine will be lessened. According to Ludwig the blood pressure causes the transudation of the blood plasm through the capillary walls of the glomeruli after the fluid is brought into contact with the epithelial lining of the tubules and into connection with the lymph around the tubules. The wa-

ter is then reabsorbed by the lymph and also by the blood capillaries. If we take account of the glandular character of the epithelium of the tubules and assume that the cells are active then we can account for the difference between the blood and the urine found in the two fluids especially the fact that certain substances are found in the urine not found in the blood. Certain substances are found in the cells indicating the cell activity, for example, the crystals of uric acid. It seems to be not so much a question of blood pressure as of the velocity of the blood flow, together with the existence of certain substances such as oxygen, urea and the salts which assist the secretory processes by acting within the cells.

The rapid rate of the blood flow assists in the secretion of urine by bringing these substances into close contact with the cells and inducing activity on the part of the cells. The secretory processes therefore take place in connection with the cells, urea, uric acid and salts being first secreted in these cells, these being washed out by the water which is filtered in connection with the glomeruli. The cell activity however in reference to these substances depends upon the rapidity of the blood flow and the amount of water found in the blood.

The blood pressure in the small vessels of the kidneys will be increased (1) by the general increase of blood pressure due to the increased force or frequency of the cardiac contractions or to the contraction of the small arteries all over the body; (2) by the small arteries in regions outside of the kidneys, for example the skin, the intestines, etc.; (3) by the relaxation of the renal artery or its main branches. The opposite condition will of course diminish the blood pressure in the small renal vessels.

Innervation of the Kidneys:—The exact nervous tracts along which particular impression travel to the vessels of the kidney are not definitely known. The nerves to the kidneys come from the renal plexus and the smaller splanchics. The section of the spinal cord below the medulla lessens or causes to cease altogether the flow of urine. This is probably due to the great general fall of blood pressure produced. If the lower end of the cord after division be stimulated the blood pressure rises in the vessels of the kidney and the urine secretion is increased. The higher centers have an influence upon the urine secretion, emotional conditions increasing the secretion. The central source of the renal nerves is found in the floor of the fourth ventricle close to the vagi roots. If the medulla is punctured in this region the amount of urine is increased and it is found to contain certain albumin and blood serum. The section of the renal nerves leads to polyuria and the specific gravity becomes lessened. The same result to a less degree follows section of the splanchnic nerves, a fact to be explained in connection with the dilation of the renal artery. The splanchnic contains the fibers of the vaso-motor nerve. The renal vessels and those of the intestine become paralyzed. On the other hand stimulation of the distal portion of the divided splanchnic nerve causes contraction of the renal artery and a diminuation or complete arrest of the flow of urine. The kidney like the spleen is subject to rhythmic variations. The kidney diminishes in size when the renal arteries contract, increas-

ing when the vessel calibre increases. The tracings that mark the increase in the renal volume indicate that the changes follow the respiratory and cardiac pulsations. Vaso-motor action influences to change in the size of the kidneys, for example, an excessive supply of blood to the vaso-motor center area produces vaso-motor stimulation causing diminution in the volume. There are no vaso-dilator fibers to the kidneys as the stimulation to the splanchnic branches of the sympathetic causes diminuation in the renal volume. There is an intra-renal nervous arrangement although it is not as yet completely understood. If water and urea are injected into the blood there is a contraction of the kidneys followed by dilatation. The same results follow when all nervous connection is cut off from the central nervous system.

MICTURITION:—The urine is continuously being separated from the blood. Passing from the orifices of the excretory tubules into the calices and the pelvis it is carried along the ureter partly by pressure and partly by peristaltic contraction of the muscular walls of the ureter and is then discharged into the bladder. Its regurgitation into the ureter is prevented by the oblique manner in which these tubes perforate the walls of the bladder and by the small valves formed by the vesical mucous membrane at the orifice of each ureter. There are three layers in the walls of the ureter, the intima consisting of a mucous coating inside of which is a muscular coating and outside a fibrous coating; connective tissue fibers constitute the tunica propria of the mucous membrane in the midst of which are found cellular elements, the tunica propria passing into a submucous coat. The tunica propria is covered with a stratified tesselated epithelium. In the pelvic portion of the kidney are racemose glands and also in the upper portion of the ureter. The muscular layer consists of two fiber coatings, the external being circular and the internal longitudinal, in the lower portion of the ureter there is a third layer outside of the other two of longitudinal fibers. The same layers are found in the bladder. Small racemose glands are found in the tunica propria of the fundus. The muscular coating consists of an internal and external layer of longitudinal fibers with a middle layer of circular fibers between them. Nerve fibers pass to muscular fibers of the pelvis and ureter and in the bladder there are also groups of ganglia. In the female urethra we find a mucous membrane whose tunica propria consists of a delicate connective tissue with numerous papillae chiefly at the external orifice. It is very vascular and contains a number of racemose glands. In the male urethra there are some differences. The epithelium of the prostatic portion is like the epithelium of the bladder while in the membranous portion it becomes stratified cylindrical epithelium and in the cavernous portion the simple cylindrical epithelium. The flat stratified epithelium exists in the fossa navicularis. Probably the urine is driven through the ureter by peristaltic contraction of the walls. It rapidly flows from the pelvic portion of the kidney into the bladder and the bladder is slowly filled as the external orifice is closed. The muscular fibers of the walls of the bladder are kept in a constant state of tonic contraction the degree of contraction varying at different times. When in consequence of the accumulation

of urine a certain amount of tension is caused upon the bladder wall, the amount of urine necessary to do this being in inverse proportion to the degree of tonic contraction of the muscular fibers, contraction of the muscular fibers set up probably reflex action and this assisted by the contraction of the abdominal muscles drives the urine with force into the urethra the sphincter vesical relaxing or the contraction being overcome. The urine cannot be driven up the ureters by bladder force. The ureter orifices being slanting, strong pressure tending to close and keep them closed. After the bladder had reached a certain limit of tension the nerves in the bladder walls are stimulated. If the tension increases the muscle fibers of the sphincter becomes contracted by reflex action, the expulsion of the urine being closely associated with the escape of a few drops of urine into the prostatic portion of the urethra. It is certain that a free flow of urine follows this occurrence. The last portions of urine are thrown off the urethra in drops this being caused by the muscular contractions of the cavernous portion of the urethra. The nerve center or centers that regulate the innervation of the bladder are situated in the lumbar region of the spinal cord. The sensory fibers from the bladder and urethra pass into the cord through the posterior roots of the third, fourth and fifth spinal nerves in the sacral region, the motor nerves regulating the muscles of the urethra and the sphincter urethra enter the cord through the anterior roots of the third and fourth spinal nerves in the sacral region. This center in the lumbar region of the cord is connected with the cerebrum by fibers which are inhibitory. It is said also that nerve fibers pass immediately from the brain through the cord to the sphincter urethra under the control of the will. When the urine is voluntarily voided this center sends down impressions to the voluntary muscles which control the sphincter. There are also vasoconstrictor fibers but their course and action are unknown. If the spinal cord is injured producing irritation higher than the lumbar centers, the distension of the bladder takes place, the urine being retained, sometimes passing from the urethra by drops. When micturition is voluntary a little urine passes into the urethra arousing sensory stimulation which excites the spinal center. This spinal center is constantly active, normally securing the firm closure of the neck of the bladder and preventing escape of urine. When the sensory impulses reach the center it is inhibited and as a result the neck of the bladder yields, the impulse from the center being conveyed to the bladder and the abdominal muscles resulting in micturition. Similarly psychic influences from the brain place micturition under the control of the will although it is objected to this psychic influence that it seems to overbear the normal tonic condition of the spinal center.

# Body Income and Expenditure.

The various processes of digestion, secretion and excretion have been discussed and the functions which are concerned, in these we come to consider the income and expenditure of the body.

The ingesta include all matters introduced into the body by the alimentary system, the respiratory system and the skin; the excreta include all that is excreted from the body by the various excretory organs. If the body weight is supposed to remain stationery the ingesta and excreta would be equal. If the body weight is increased then the ingesta must exceed the excreta. There is a continual excretion from the lungs of $CO^2$ and $H^2O$; from the kidneys of urea, uric acid, water and salts; through the skin of $CO^2$, $H_2O$ and fatty matters. There is also a daily loss in connection with the hair, the skin, in connection with the secretions of the stomach, intestines, etc. The body is continually gaining oxygen, water, albumin, fatty substances, salts, etc. The proximate principles of the body we have seen consist chiefly of water, albumin, carbohydrates, salts and gases. The carbohydrates form only a very small percentage of the body weight, so small that they may be omitted from the income and expenditure of the body. Volkmonn estimates that in every 100 parts of the body we find 64 parts of water, 16 parts of albumin and gelatin, 14 parts of fat, 5 parts of salt and 1 part of carbohydrates. The muscles of the body contain 75 p. c. of water and about 22 p. c. of albumin, and as the muscle constitutes about 43 p. c. of the body weight, from this it is evident that 50 p. c. of the water and albumin of the body is found in the muscles.

1. Water. This is present in all the tissues forming about two-thirds of the body weight. The amount of water is estimated by taking the amount of water taken in as food or drink, and the amount of water excreted by the intestines, the lungs, skin and kidneys.

2. Albuminous Matter. The nitrogenous matter excreted as urea, uric acid, etc., must be estimated and from this form an estimate of the amount of such nitrogenous substances which undergo change in the metabolic processes. The amount of nitrogen used up in the alimentary canal may be estimated by subtracting from the amount taken as food, the amount in the faecal discharge. In the albumin, etc. it is estimated there is 16 p. c. of nitrogen. Therefore one part of nitrogen will be equal to 6 1-4 p. c. of albumin. According to Vost one gram of nitrogen represents 30 grams of flesh substances.

3. Fats. The principal fats of the body are olein, stearin and palmatin. If we subtract the volume of carbon in the albumin passed through the metabolic changes, the albumin containing 53 1-2 p. c. of carbon, from the amount of carbon excreted by the intestines, lungs, skin and kidneys, the balance will represent the amount of carbon that has passed through metabolism. In the fatty substances there is about 76 1-2 p. c. of carbon.

4. Salts. By making an estimate of the salts in the food and subtracting from it the salts excreted in the urine and faeces

we get the amount which passes through metabolism in the body. If we take an animal during starvation in which only one or two substances are given as food. In the case of a man who abstained from meat for days at a time the loss per day was found to be 890 grams of water, 78 of albumin, and 215 of fat. It is found that during starvation the amount of nitrogen decreases until it reaches a steady limit, the loss of nitrogen being in a direct ratio to the loss of the body; the loss of $CO^2$ is diminished below the ratio of the oxygen absorbed until it reaches a limit which remains constant until death results. It is estimated that when an animal is starving the loss may be represented; supposing the total loss to represent 12 parts, there will be a loss of 8 parts of water, 3 parts of fat, and 1 part of albumin. If water is furnished equal to the loss of water then the loss in the other substances will be reduced between 60 and 70 p. c., indicating that life can be sustained longer upon water alone than any other of the proximate principles. In the case of food given to supply the loss, it is found that if albuminous materials are given equal to the loss of albumin, the loss of albumin is not arrested for the nitrogen in the urine increases and the body loss still continues. This is due to the increased metabolism of the body which can use up a larger amount of albumin. In the case of the dog it is estimated that from 2 to 3 times more of nitrogenous matters must be given as food than we find excreted. Vost has estimated that to restore equilibrium and prevent body loss one-twentieth of the body weight must be given in the form of flesh food; if more than this amount is given then the animal begins to increase in weight and there is less nitrogenous waste eliminated. If, however, a flesh diet is maintained there must be a daily increase in the amount of flesh given as food until it reaches a point where the animal will be incapable of digesting the amount of flesh that must necessarily be taken in order to preserve this condition. It would seem that if the albumin is increased the loss of fat is diminished. If no albumin is given as food, the use of large quantities of fat does not diminish the albuminous metabolism. Similarly the use of large proportions of carbohydrates does not diminish the albuminous metabolism, but there is an increase in the excretion of the water. If both albumins and fats are given freely as food then the albuminous metabolism is diminished. Thus a combination of fat and albumin in food tends to preserve nitrogenous equilibrium. The carbohydrates, like the fats used as food, tend to preserve the albumin For this reason the carbohydrate food in animals feeding preserves the albuminous balance at less expenditure than by the use of fats. Vost estimated the income and expenditure in the case of a man weighing 70 kilograms—

1. In active work when the metabolism is complete: Income, 137 grams of albumin, 117 of fat, 352 of carbohydrates and 2265 of water, representing 19 1-2 grams of nitrogen and 315 1-2 of carbon. Expenditure in urine, faeces and by the lungs, 19 1-2 grams of nitrogen, 336 1-2 of carbon, and 2700 of water.

2. In the case of a healthy individual not actively engaged in work: Income, 137 grams of albumin, 117 of fat, 352 of carbohydrates, 2016 of water representing 19 1-2 grams of nitrogen and 315 1-2 of carbon. Expenditure in urine, faeces

and through the lungs, 19 1-2 grams of nitrogen, 275 1-2 of carbon and 2190 of water.

In the first case there was an excretion of 434 grams more of water and 20 grams more of carbon than that represented in the income, while the amount of nitrogen was not increased. Therefore in order to prepare a man for active work so as to compensate for the loss of carbon, more fats and carbohydrates must be given in the food. In the case of the person not actively working, but healthy, there is a loss of 174 grams of water, but 40 grams of carbon are stored up in the body. This has a bearing upon dietetics for the carbon producing substances in the food may be lessened, that is the fats and carbohydrates, in the case of a person not actively engaged in work. The temperature has also an important bearing upon the body metabolism. If the atmosphere is cold the $CO^2$ excreted is increased and there is needed in the food more fatty substances. If the atmosphere is warm less $CO_2$ is excreted and less fatty substances is required in the food. The nitrogenous matters are not effected to any great extent by the hot or cold temperature. Generally the body may be regarded as a mechanism for the transformation of food materials into potential energy. The body metabolism involves the conversion of these materials into energy in the form of labor and animal heat. This conversion implies the oxidation of the food substances into their corresponding waste products. It is estimated the amount of potential energy contained in a normal daily diet and thus estimate the energy accumulated in the bodily system daily. These estimates have been made by calorimetric calculations. It is estimated that one gram of proteid represents 4500 calories and 1 gram of fat 900 calories and 1 gram of carbohydrates 4000 calories. According to Ranke a normal diet consists of 100 grams of proteid, 100 grams of fat, and 240 grams of carbohydrate which on the above caloric basis would yield 2, 310,000 calories. This would represent in round numbers 1,000,000 Kilog. metres of work. This energy thus accumulated is expended in two ways (1) mechanical labor and (2) animal heat.

I. By Mechanical Work:—In locomotion and muscular work, in respiratory and vocal movements the body expends its energy. All the material work of the entire bodily system together with the external work of the body, mental activity and cardiac action unite in the expenditure of energy. An average day's work including exercise is estimated at 150,000 kilog. meters. Older physiologists estimed that all the nitrogenous food went to the upbuilding of the tissues including the muscles and that the nitrogenous waste arose from the metabolism of the body in its separate organs, the non-nitrogenous being used in connection with heat and respiration, the excess being stored up as fat. This view however as we have seen requires modification, the muscle tissue not being supplied solely by the proteids and muscular activity not depending entirely upon proteid nutriment. As we have said before it is not the muscles alone that feel the drain upon them of labor, the circulatory and respiratory system and in fact the whole body being drained by active muscular exercise. The urea for example as we have seen is not necessarily increased by severe labor. Certain con-

ditions however may arise in which such an increase does take place. The muscular energy must draw upon some other sources than proteid metabolism. Muscular exercise increases the production of $CO^2$. It is estimated that work for one hour will cause a five fold increase of $CO^2$ given off in a single hour. The muscular energy does not depend then upon an exclusive proteid metabolism.

2. Animal Heat:—The animals are either warm blooded with a constant temperature or cold blooded with a constantly varying temperature, depending largely upon the medium in which the animal lives. The temperature of the human subject estimated from the axillae is about 36° to 37.5° C., the changes in in a normal heath condition not usually exceeded one half a degree. The temperature of the bodily organs is normally higher than the superficial body temperature. Claude Bernard found 40.5 C. as the normal temperature of the lungs, muscle and brain. The blood in the right side of the heart is warmer than that brought back to the left side of the heart from the lungs, the blood being cooled in the passage through the lungs. There is a variation in the warmth of the blood depending upon the location of the blood. There is a daily variation in the body heat representing the different degrees of heat at different periods of the day. It is lower in the morning, gradually rising until the middle of the forenoon then sinking about noon, rising towards the middle of the afternoon and then sinking toward evening and during the night. These changes are said to be due to the food, as no such changes occur during deprivation of food, when the temperature falls lower than the normal. The body heat depends on (a) chemical changes. The tissue changes are all chemical changes, these resulting in the setting free of heat. The amount of heat liberated can be estimated as the oxidation process always produces a certain amout of heat. All the chemical changes of the body produce heat. This is proved by the fact that the variation of temperature depends upon the amount of $CO^2$ excreted. (b) Body heat also depends upon the mechanical activity. Muscle movements, locomotion, friction and general body activity produce heat. The muscles represent the organs in which the greatest amount of heat is produced. This is shown by the fact that the blood leaving a muscle is warmer than that entering it, and also by the active changes taking place in the muscle itself. The nervous system, especially the centers, and the various glands of the body are also heat generators. The amount of heat may be measured by calorimetry. Lavoisier used the water kalomimeter. The animal is placed in a metal box, the air being supplied and the $CO^2$ being drawn off. The box is then placed in a water or ice media surrounded by non-conductors of heat. The temperatures of the water and animal are taken at the commencement and after some hours. The amount of heat is then estimated in heat units, a caloric being the heat necessary to raise the temperature of a kilogram 1° C. Hirn estimates that 2700 calories represent 112 ca. per hour; during work the daily average rise to from 3500 to 3750 ca. This heat produced in the body and in its organs is distributed in part by the blood circulation and partly by the physical principles of conductivity. The law of conductiv-

ity applied to the body is that the amount of heat passing from one part of the body to another increases with the cross section of the tissues intervening and the density of the intermediate medium and the difference in temperature in the two portions of the body. The loss of heat takes place from space to space by radiation and by the heat passing into a latent condition, the blood vessels possessing a fluid that is normally in rapid circulation represents the great medium of the distribution of heat, the blood tending to equalize the temperature of the different parts of the body. Heat is lost from the body in connection with respiratory process and the process of alimentation in the heating of cold food substances. Of 100 ca. of heat it is estimated that 80 p. c. passes off by radiation, 15 p. c. by evaporation, 2 1-2 by respiration and 2 1-2 in the process of heating food. Thus a large percentage is lost in connection with the skin indicating the importance of the skin in connection with animal heat. This forms the basis of hygenic conditions, relative to clothing, as the wearing of warm clothing next the skin prevents the rapid cooling of the body, thus maintaining normal animal temperature. To maintain the animal temperature is one of the necessities of life in the case of the human subject so that the problem of animal heat is really the balancing of heat production and heat loss. This is accomplished chiefly in connection with the circulation and the skin. Cold lessens the heat loss by lessening the blood flow through the skin, lessening the sweat secreting and thus lessening the amonnt of heat that becomes latent. Clothing that is a nonconductor of heat also prevents the loss of heat by keeping a warm air around the outer surface of the body. Helmholtz estimated the amount of heat gained and lost in a day.

THE HEAT GAINED:—877 1-2 grams of $CO^2$ is given off daily and this oxidation involves the production of 1731 ca. of heat. More O is taken than is found in connection with this excess of $CO_2$, this excess oxidizing Hirst's $H^2O$, 13 1-2 grams of H production, 318 1-2 ca. This would give 2049 1-2 ca. Aside from these internal processes 1-4 of the body heat is derived from other sources, clothing, artificial heating etc making a total of 2732 ca.

HEAT LOST:—About 80 p. c. is lost by radiation, conduction and sweat evaporation or 2194 ca. About 14 1-2 p c. by evaporation in the lungs or 397 1-5 ca. About 2 1-2 p. c. in heating air and 2 1-2 p. c. in heating food or 140 ca. Heat regulation is carried on within the limits or from 37.5° to 40° C. If the temperature rises about 44° C there is rapid pulsation of the heart and respiratory activity, resulting in rapid death. The nervous influences upon temperature is not as yet known. This is due to the increased flow of hot blood arising from the dilation of the blood vessels. If the spinal cord is divided the temperature falls, due probably to the dilation of the blood vessels over the body producing loss of heat by radiation and conductivity. In the case of death from fevers there is a rise of temperature after death indicating the production of heat even after death, supposed to be due to the blood coagulation and the sudden cessation of respiration and circulation, less heat being lost in the case of a dead body than in the living body. A persons sen-

sations, the feeling of cold or heat, are no true index of the actual state of the bodily temperature for these sensations are determined by the amount of blood in the cutaneous vessels. Thus when the vessels are contracted a person will feel cold even though the temperature of the blood is abnormally high as actually takes place in cold stage of fever.

# The Nervous System.

The physiology of the nervous system is dependent for its elucidation (1) the anatomy of nerves in their origin, course and relations. (2) The histology of nervous structures particularly studied in connection with the different stages of development from the embryo to the adult condition. (3) Pathological observations have emphasized changes due to diseases and abnormal conditions. (4) Experiments in connection with the division and the stimulation of divided nerves have in recent times furnished a mass of evidence that emphacizes the functions of certain nerves and indicates, if it does not directly prove, the relation of certain nerves to organs and other nerve channels. When the nerves were found to terminate in muscles they were supposed to be motor, those in connection with the organs of sense were supposed to be sensory nerves. The cerebral enlargement found in the higher animals as compared with the lower animals was supposed to be connected with the psychic development of the human subject. In later times experiments in connection with the nerves divided have opened up many new facts in regard to the nerve centers and also the different nerve paths. If to these are added histological observations as to the structure and course of certain nerves there is a pretty complete knowledge gained of the functions of the nervous mechanism. In the embryo the central nervous system arises from the epiblast. The white and gray matter of the spinal cord and the brain originate from the medullary infolding. The sympathetic system including the nerves and gangha connected with it, toward the periphery also arises from the epiblast. This epiblastic layer also gives rise to the sense organs, the organs being expanded in such a way as to become specialized in the reception of impressions of a definite character. These sense organs therefore originated from superficial cells which under the influence of certain definite stimulation cause to be specialized in function. These specializations became the centers of organic function, communication being established with neighboring cells, these channels of communication being differentiated as special nerve paths. This course of evolution may be followed distinctly in the field of comparative physiology. In the medusae, for example, we can trace the movement from nerve epithelium in the primitive cell form to the ganglonic center, two kinds of cells being found; (1) a primitive cell in which we find minute hair like processes extending outward to the superficial part of the body; (2) a modified cell in which the hair like process is lost and the regular cells have been developed. In this way from the stand point of evolution

and embryology the entire nervous system arose from the modified sense cells, the connection with muscles being of later development. It is only in the higher forms of life that we meet with muscle connection complete in connection with the nerve fibers. This connection between muscle and nerve is supposed to be established by the relations established between neuro-epithelial and myo-epithelial cells so as to form neuro-muscle plates. The nervous system in the human subject developed by evolution out of the simple epiblastic layers, when fully developed is found to consist of three parts; (1) ganglia representing the masses of the brain, the spinal cord and the ganglia connected with it; (2) terminal organs or plates found in the connection with the sense organs or the muscles and (3) the nerve or nervous path connecting the end organs with the central nervous system. These nerves are paths along which nerve forces travel, the force originating in the end organs or in the nerves by stimulation or else in the nerve centers. Stimulation applied to the nerve path along its course gives rise to iritation which pases along the nerve to a center or an end organ resulting in the production of certain phenomena of movements, feelings, sensations, etc. Stimulation may originate in an end organ the stimulation being transmitted along a nerve carrying a sensation or a change resulting in action, movement, or feeling of some kind. Similarly stimulation may arise in a center or centers the impulse being conveyed along the nerve path terminating in the muscle and producing some kind of action. The fibers of the cerebro-spinal nerves are bound up in a sheath of loose connective tissue. The epineurium sends down divisions into the internal of the nerve dividing the nerve into bundles, the nerve fibres being bound in minute folds, all these coverings being continuous with the connective tissue of the external perineurium. The fibres do not divide except near certain terminals, although the fibres join from neighboring trunks and become closely bound together.

In the sympathetic system the fibers are non-medullated and hence are much brighter in color than the cerebro-spinal fibers. In the large nerve cords there are capillaries together with lymph spaces found in connection with the epineurium and the perineurium. Along the path of the nerves there are groups of ganglion cells found either in round masses or in elongated fibers. Around the external surface of the ganglion there is a covering, the continuation of the epineurium, consisting of loose connective tissue. In these ganglia we find large numbers of minute capillaries, these capillaries surrounding the cells in order to carry on the active nutrition of the nerve tissue. In the cerebro-spinal system the ganglia have large ganglion cells, each cell being surrounded by flattened endothelial cells. If the nerve fibers enter the ganglia medullated they lose their medulla and issue from the ganglion non-medullated. In the sympathetic system the ganglion cells are smaller and are multipolar as distinguished from the unipolar cells of the cerebro-spinal cells.

In the gray matter we find both fibres and cells so that these cannot be separated on the application of stimulation. The stimulation of the gray matter either depends largely upon the supply of blood

and also upon the rapidity with which the waste matters are taken away. If the blood supply is not sufficient or if the carrying off the waste products is incomplete then the nerve cells become inactive or suffer through lack of proper nutrition. If the blood supply is cut off suddenly the change is so sudden as to produce unconsciousness. Similarly the absorption into the blood of chloroform or ether will induce unconsciousness. In many diseased conditions the blood becomes so vitiated as to be incapable of carrying on the vital functions, the result being some form of delerium. The nerve cells thus depend upon the normal activity of the blood supply and upon the favorable conditions involved in the equilibrium of the various centers, the disturbance of this equilibrium resulting in abnormal condition. The gray matter consisting of nerve cells from the chief parts in which reflex centers are located and these reflex centers are connected with one another by the nerve fibres.

Sensations involve consciousness in connection with an impression, these impressions made upon sensory nerves being conveyed to the nerve centers. Often stimulation produces movement indirectly, the impressions passing along nerve paths to a center from which certain impulses are passed to other organs or muscles by nerve fibres. If the brain and medulla of a frog are removed and if stimulation is applied to the foot the limb will be drawn up. This is said to be due to reflex action, reflex action taking place without consciousness,in which case we have (1) the stimulation of the sensory nerve; (2) the carrying of this impresssion to a reflex center and (3) the bearing of a motor impulse along an efferent fibre, resulting in action or movement.

The Evolutionary Development of the Central Nervous System:—It is almost impossible to appreciate the functions of the central nervous system without tracing the development from simple structure to complex structure, and from simple function to complex function. Among the invertebrates we find nervous systems consisting of ganglion or chains of ganglia whereas among the vertebrates we find nerve tissue formed into a spinal cord and terminating in a brain. In the most primitive animal forms of nervous system we find the cell of protoplasm forming the center of activity and sensation. As soon as the cell coatings become numerous and independent of each other sensation becomes associated with the external layer. As soon as the sensory system becomes of importance to the organism parts of the sensory layer enter into the body or deeper structure of the organism, the outer parts becoming differentiated as well as the inner; the superficial parts representing the organs by which connection with the external would be established, this connection being transmitted by impulse with the deeper parts or ganglia by means of processes, communicating from the external to the internal. These processes from the internal to the external pass into communicating fibres. The forming of the nervous system follows the structure of the animal, for example. in the starfish, the nervous cord is symemetrical with the body arrangement As the body becomes more complex the nervous arrangement is more complicated the cord and ganglia being arranged from the different portions of the body, these

being arranged together by a central cord or chain of ganglion. In the vertebrate the enfolding of the epiblast originates the nervous cord that forms the cerebro-spinal axis. This primary cord is widened at the upper end, and then subjected to restriction, and this forms the three cerebral portions which form later the anterior, middle and posterior portions of the brain.

This primitive cord appears in tubular form, the tubular cavity becoming the spinal cord and the thickened portions representing the brain, the spinal cord in its tubular cavity representing the embryonic tubule condition of the nervous matter. The three cerebral portions are formed by the loops called the fore, mid and after brain. From the anterior loop there is formed by protusion first a single and then double parts, representing the cerebral hemispheres, which are separated from one another by the median line. Out of each of these vesicles there arises the olfactory lobe, the remainder of the hollow cavity of the vesicle becoming the third ventricle. At the outer and lower walls of the hemispheres there are thickenings which correspond with the corpora striata, representing the floor of the hemispheres. Right behind the corpora striata there are two thickenings of the circumferentiated wall which become the thalami optici, the fine layer lying between the two being called the taenia semicircularis, the hollow tubular cavity forming the cavity lying between the thalami to the cerebral cavities being the foramen of Monro. The floor of the third ventricle is posteriorly formed by tegmenta of the crura cerebri, being formed into a conical process at the end of which is the pituitary body. The roof of the cavity is delicate, being limited by the anterior and posterior commissure, the pineal body being developed in connection with it. From the one corpus striatum to the other there pass fibers which form the white commissure, the gray commissure connecting the two thalami optici. The corpus collosum connect the two hemispheres, in highly developed brains it crosses considerably higher than the level of the fornix, intercepting a part of the internal wall of either hemisphere. The two internal walls form the septum lucidum, the space between constituting the fifth ventricle cavity. When the floor of the middle loop thickens there are formed two large groups of longitudinal fibers forming the crura cerebri, the optic lobes being developed on the roof. The third loop in its development remains practically unchanged as compared with the other two loops. On the upper wall we have a very fine surface anterior to the cerebellum, forming a lamina, the posterior part being covered with membrane and opening into the posterior sub-arachnoid cavity. The cerebellum first appears as a fine medullary lamina, arched posterior to the corpora quadrigeminia, the epencephelon forming the cerebellum, pons vorolii and the frontal portion of the fourth ventricle, the metencephelon forming the medulla oblongata. The complexity of the structure of the brain of the higher animals are greater for the increased development of the cerebral hemispheres and vary in the progress of development these hemispheres project forward beyond the primitive first loop; as they develop upward they take the place of the second loop, filling up the most prominent portion of the head; as they develop down-

ward and to the sides they constitute the temporal lobes In this way we have the development of the frontal, parietal and temporal lobes. Still later by the posterior development the occipital lobe, constituting the crebrum so that it occupies a position high up in the head and covering entirely the lower portions of the brain. Thus the hemispheres enlarge from the small loops of the early embryonic brain until they occupy a position above all the other portions of the brain. During the progress of this development the superficial gray matter enlarges to such an extent that it is thrown into an immense mass of convoluted furrows. The superficial surface of the hemispheres is primarily smooth, the first division being noticeable between the temporal and frontal lobes, afterward developed into the Sylvian fissure. Later we find the separation of the occipital and parietal lobes taking place in connection with the verticle fissure and the frontal and parietal lobes by the fissure of Rolando. It is after the formations of these dividing grooves that the convolutions begin to form, first by the formation of shallow and indistinct furrows and then later by the deepening of these furrows and the continued extension of subordinate furrows It is in connection with these convolutions that psychic development takes place, the greater the psychic development the more marked the convolutions become.

Arising from the same characteristic type we find the brain development in the animal kingdom gradually more complicated, the brain found in the lower animals corresponding with the lower stage of development in the higher animals. Among the fishes, for example, the brain retains its embryonic characteristic, consisting of a number of protuberances either in pairs or singly. In some of the lowest forms there is no brain proper, the cord being continuous without any enlargement. In the cyclostomata we find the development nearer the primitive embryonic form, as the five characteristic portions of the brain are distinguishable, the chief development being in connection with the ganglia that represent the sense organs. In higher forms the cerebral part of the brain is developed, the lobes of the brain being characteristic and the medulla being large. Among the amphibia the two hemispheres are fully developed, while in other forms the cerebellum is distinctly marked, although small. Among the birds the hemispheres of the cerebrum are fully developed, the middle brain being concealed beneath the hemispheres, connected together by a commissure. The middle part of the cerebellum is arranged in layers of gray and white matter. There is not found the pons varolii or the corpus collosum, but there is a mass of matter arranged in ganglionic form corresponding with the corpus striatum and the thalamus opticus. Among the mammals the cerebral hemispheres are fully developed, being connected by the corpus collosum. This commissure magna is small and is limited to the anterior portion of the hemispheres; in the lower animals it extends to the posterior portion. The hemispheres in the lower mammals are not large, have no lobular divisions and few, if any, convolutions. The hemispheres extend posteriorly over the cerebellum and medulla. In the transition to the higher orders we find lobular divisions and frontal develop-

ment of the cerebrum. In the higher mammals the superficial surface of the brain becomes convoluted, the convolutions varying considerably in different animals. The cerebrum also becomes more complex. Originating in a simple layer in the lower animals, it becomes definitely marked in the transition to the divided portions constituting the lobes. In the spinal cord there is not much variation among the different animals. In the center of the cord is found the gray matter, being surround by white matter, the gray matter being most abundant where there are areas connected with limbs. In the higher animals the cord can be divided into columns. The mass of the cord depends upon the nerves that branch from it, being largest in the region of the higher vertebra from which the limb development takes place. The development of the cord is marked distinctly in regions representing the cervical, dorsal and lumbar areas.

The enlargement of the brain corresponds somewhat with the mental capacity of the higher animals. Allen Thompson, who is one of the greatest authorities on cranology, says that cranial capacity is larger among the civilized people than among the uncivilized and even among the civilized there is a noticeable difference between the educated and intelligenct over those of average or inferior mental capacity, In the case of the apes the brain is much inferior to that of man in weight and size. The gorilla brain is less than one-third, and the orangoutang brain less than one-fourth of the human brain. In the ape and gorilla the brain is about .01 part of the body weight, while in man it varies from one-fortieth to one-fiftieth. At birth the brain of a child is about one-tenth the weight of the body; at three years the brain has developed to about three-fourths of the adult size; at the close of seven years it has developed to about nine-tenths of the regular size, the other one-tenth being slowly developed from 7 to 25 years.

In connection with this brief embryological account of brain evolution it is to be noted (1) that the principal part of the cerebro-spinal system is the medulla and spinal cord. This portion of the nervous system is found among all vertebrates and constitutes the nerve basis of locomotion, circulation, respiration and mentation, together with the tactile sensations. (2) In the differentiation of the higher centers certain parts of the frontal portion of the cerebro-spinal system are developed, the developement taking place always posteriorly and downward. The first developement in this direction is the sense division, hence division development marks the lowest forms of animal life. Following this we have the development of a region of the thalami optici specialized in connection with the sense of touch, the sense of smell localized in the anterior part of the prosencephalon, indicating that it makes one of the first special organs, thus smell, vision and touch are the three primary centers. The auditory region from which spring the auditory nerve is located in the medulla indicating the early character of hearing in close connection with the oblong marrow representing expansion of the spinal cord, similarly the sense of taste originates in connection with the medulla from which arize the gustatory nerves. (3) Following the differentiation of different senses

and the different sensations connected with the senses we find the origination and developement of ideas representing psychic changes corresponding with mental phenomena of judgement, memory, emotion, volition and intellect, the cerebrum being more fully developed according to the mental phenomena manifested by the animal life. The mental condition is proportionate to the brain developement. We find a gradual increase as we increase in intelligence, as we advance from the lower to the higher animals, the brain becoming more complex. The prosencephalon is regarded as a portion of the brain, in which mental capacity and activity are localized, this part of the brain enlargement is commensurate with intellectual development. (4) Connected with the cerebellum developement we find the co-ordinate movements of the different parts and organs of the body. These movements vary considerably in animals from the fish up to man, representing different stages of development for the simple back and forward movement of the fish fins to the rotary movements of the birds wings up to the delicate movements of the front limbs in the human subject. The development of the cerebellum from the simple to the complex represents the adjustment of these co-ordinate movements to the special form of animal life. Cerebellum development marks particularly the high degree of development found in man. As we have seen in the human subject each part of the cerebro-spinal system represents a marked improvement from the lower forms of life, the characteristic high developement of the spinal cord, cerebrum and cerebellum, indicating the final point of perfection reached in the case of the highest of all animals. This is in line with complexity of the bodily system as found in man and also the psychic conditions represented by intelligence, emotions and will by which the vegetative functions are discharged in the maintenance of life and species and also the animal functions by means of which he is conscious of a world outside of himself and brings himself into conscious relation with this outside world. Thus it is the nervous system in man in all its complex bearings that places man at the head of all species of creatives, endowed with pre-eminent glory as the climax of all development.

The human nervous system is continuous throughout the entire system, the nerve tissue consisting of minute nerve cells all arranged together to form a united system. In the division of the nervous system into parts, therefore, the analysis is artificial and the anatomical separation has no physiological significance except in tracing and emphasizing connections. The continuity of the nervous system is the means of uniting all the different parts of the body, the impulses being carried along the different nerve paths with the result of uniting these parts in harmonious action and continuous activity. In addition to the unison of all the parts an important factor is found in connection with the other fact that all impulses must travel to the central nervous system. As we have seen in the development of the nervous system from an immature to a mature condition the increasing evolutions of the parts and of the whole nervous system goes on side by side with the complete organism of the system so as to complete the connection of all the parts. The connections

become also more delicate and are more freely and firmly established so that relations that formerly were impossible became perfectly natural. The increased complexity of the system then involves the greater efficiency of the nervous mechanism and its better adaptation to the functional activity. This adaptability implies the possibility of so regulating the development of the system as to make it capable of doing what otherwise under different conditions it could not do. It is here that we come to the realm of consciousness and enter the field of conscious development, for while physiology alone is the science with which we deal in discussing the nervous system, it cannot be forgotten that psychology explains many of the physiological phenomena and particularly the modifications taking place during physiological development, which results in a higher nervous condition than that found apart from consciousness.

Physiology of the Nerve Cell:—The nerve cell consists of a cell substance including nucleus and cell branches. These nerve branches may be prolonged so as to form nerve fibres or they may be shortened simply forming protuberations. The nerve cell includes the cell substance and its branches together with the nucleus. There are great differences in the nerve cells, the branches varying and also the shapes of the cells. In the main cells there is a cell body and one principal branch called the neuron in relation to the cell. The cells from this standpoint are sometimes arranged according to the number of their branches, mononeuric, dineuric. In connection with the neura we find also subsidiary branches. The branches often assume a complex appearance in the form of branches from a tree trunk. The cell is normally oval in shape, although it is subject to much variation, the diameters of these cells varying from 1-100 to 1-10 of a millimeter. In connection with the cell substance two elements have been found, the one constituting a stroma which is continuous with the minute fibres of the nerves, and the other a granular mass enclosed in the meshes of the stroma. These granular masses are very subject to stimulation indicating the variations that take place in connection with nerve irritation. These nerve cells are large compared with other tissue cells the neucleus being small, decreasing as the cell enlarges. The greater characteristic of the cell is the extent of its principal branch being the enlargement of the cell substance, these branches varying in certain cases from 50 to 100 centimenters. When the cell body is estimated, for example the cells found in the cortex cerebri, we find that they contain about 4000 cubic micra, the volume of the cell neuron varying according to the length of the branch. The minute subdivisions of the branches represent a larger volume than the cell body. The cell body and the branches vary in the diffent animals being larger proportionally in man than in the lower animals. This is due of course to the simple structure of the nervous system in the lower animals as compared with man. In the human subject these large cells represent a great number of living elements in which we find stored up energy, this stored up energy being found in connection with the cell substance and being liberated under stimulation. When these large cells branch very abundantly we have connection freely and fully estab-

lished with the surrounding tissues and organs indicating not only large energy capacity but also large distributing power in the case of such energy being liberated. The elements of these nerve cells arise from the embryonic epiblast, the germinal cells dividing in the formation of new cells, one of the new cells taking the place of the old and the other migrating further from the surface so as to form a neuroblast. These neuroblasts are at first migratory cells possesing characteristic amoeboid movements. These movements are determined by the principle of cellular attraction and repulsion, their position after the close of the foetal life in the adult determining the character of the tissue. In the early stages of neuroplastic growth the cells become polarized, that is, the point of neuron growth becomes fixed and no variation can take place afterwards. When the cells, after development become mixed, the neuron not occupying its proper position we find an arrangement such as exists in the brain of cogenital idiocy. During the development of the nerve cell we find in addition to the neuron polarization and growth, the formation and development of the minute branches, together with enlargement of the substance of the cell and neuron, and the chemical change that takes place in the cell substance. In the classification of the cell the neuron is most important. The physiological value of the cell in its relation to the nerve impulses constituting a channel for nerve connection. When the impulse enters the cell it travels through it and along the neuron. In the primitive cell all the different branches performed this function, from the stimulation of the part of the cell or of its branches established communication with the entire cell.

In the formation of the branches they become therefore nerve paths along which impulses pass usually entering along one branch and passing out along another branch or other branches. In the human subject we find two varieties of these branching cells, the one in which numerous branches arise both in connection with the neuron and the minute subdivisions, while in the other we find simply two neuræ arising out of the cell body, these branches being medullated and running in opposite directions. These can only be followed in connection with their evolution. In the last case the cell must have been bipolar each pole giving origin to a neuron. It has been inferred that two fiber paths are bound up in the single branch representing the spinal ganglia and the cells found in the cortex cerebelli, the single branches having a two-fold function of leading out and taking in the impulses to the cell body. This gives us two classes of these cells—(1) those in which we find a single path. Primitively the cell had two neura at each pole but these in the evolution of the cell have been connected together in the same branch, the impulse passing in and out along the same branch which represented a double pathway; (2) we have the cell which has a neuron and various branches, the impulses generally coming in by the branches and leaving along the neuron. When the characteristic type of cell has been developed there is a continous development in size the diameter increasing to four or five times its original size. In the neuron branch we find an axis cylinder encompassed by a medullary sheath. Two opinions have been

advanced as to the origin of the axis cylinder. The first is that the axis arises out of minute filing fibers moving aside a peculiar plasma that coalgulates around the fibers, the fibers being the nerve impulse conductors. According to the second view there is a spongy stroma intermingled with a plasmic substance. According to the first theory it is claimed that we have an explanation of the different kinds of fibers found within the same nerve but these minute fibers do not pass through the sheath without branching as these fibers become divided at least toward the peripheral ends, these branches being too numerous to permit of believing that along the whole path these isolated fibers range unbroken. On the other hand if the axis cylinder consists of a series of minute tubules formed amid the meshes of the spongy stroma at varying angles the anastomosis will be so frequent as to prevent the possibility of regarding the pathway of impulse as isolated and continuous along the entire axis cylinder path. As the axis cylinder becomes enlarged these minute tubules are increased as it derives nutriment along the whole course of its path and not simply from the cell substance at the one extremity. When the branches of the cell have developed then begins the formation of the medullary sheath; the branches are not all medullated and the medullation is not complete. Both in the sympathetic and the cerebro-spinal system we find numbers of unmedullated fibers. The physiological value of this sheath is unknown although it is suggested that it insulates the fibers within the sheath so as to preserve intact the channel through which the nerve impulse passes, thus preventing a break in the impulse communication. Others think that its existence for trophic purposes in order to sustain the normal nutrition of the nerve fibers. It has been found by the application of stimulation that certain fibers loose their irritability and their power of conductivity at the point where a strong electric stimulation is applied. This is particularly so in the case of the vaso constrictor fibers. This only occurs where the fibers are unmedullated. The medullated fibers are originally nonmedullated and it is claimed that medullation represents the highest point of development in the case of the nerve cell with its branches. In proof of this it is said that some of the fibers do not attain to their functional activity until they become fully medullated. It is a question however whether this depends upon medullation or upon the establishment of connection with other cells or tissues, this connection being supposed by some to be the basis both of functional activity and medullation. By establishing connections with the branches of other cells or with the tissues a pathway for the passage of the impulses is opened up and in this way the fibres become active. This connection, however, is established in the case of the nonmedullated as well as the medullated so that medullation does not necessarily determine function. Wherever medullation takes place the sheath is formed before the maturity of the nerve fibres. In the peripheral parts medullation is determined by the existence of certain nerve cells that form an encompassing sheath around the nerve fibres, the various cells being regulated by nuclei about the cen-

ter of the cell substance. The point of connection between the cells represents a notch in the nerve fibre. The sheath becomes thicker as the axis cylinder develops, the proportion between the axis and sheath being maintained in the gradual developement. As the fibre grows the distance between the notches also increases. These nodular segments representing the trophic centers, the many nodes indicating the conditions in favor of proper nutrition in the normal interchange between the fibres and the plasmic substance. Hence where the nerve fibres are most active these notches are more numerous. In the central system medullation takes a longer time to complete as compared with the peripheral system which is completed before the end of the fifth year; in the central system the proces goes on from 30 to 35 years

The medullated sheath is not found upon the neuron close to the cell or in connection with the branches when distributed in tissues, the sheath representing therefore a physiological function in connection with the middle portion of the nerve fibers. The medullation therefore is not progressive but represents complete development. Some of the branches of the neuron are also medullated, this taking place when the branches form their connections, the medullations representing complete development. During the progress of these changes in the neuron and the branches, the cell body is also changing. The chromatic substance in connection with the cell substance becomes more plentiful on account of the increase in number of the pigmentary granules. This nerve cell while it progresses with the development of life also declines with the decay of life. The evolutionary processes that characterized the changes from immaturity to maturity are reversed, the cell substance is diminished in size, the neucleus becoming smaller, the chromoplasm is diminished, the cell substance contains large vacuoles, the minute branches become atrophied and the neurons also diminish in size. This process of shrinkage may go on until the entire nerve cell disappears by absorption. In this way accompanying the diminuition in volume we find a corresponding decrease in cell activity and a decrease in the power to influence other cells.

These nerve cells form the nerve path along which certain influences travel. This implies that in the nerve cell there are receiving and transmitting impulses. The impulse when communicated to the nerve cell is manifested in an undulatory molecule variation transmitted along the fibers from the point where the impulse originates. The variation represents an electric impulse moving with a certain velocity depending upon the condition of nerves, warmth increasing in rapidity the and cold diminishing it.

It is estimated that in the human subject an impulse travelers with a velocity of about 35 mm. per second. Stimulation can be applied at every point along a nerve fiber if the stimulation is sufficiently strong and if the fiber is sufficiently subjected to stimulation. Such stimulation may be applied in the form of heat, electricity, chemical or mechanical stimuli, but all of these are artificial and consequently differ from normal stimulation arising from the cell changes, these artificial stimuli producing a stronger variation. When a nerve impulse starts it continues to travel along the same

nerve path until it reaches some central point where it is received or distributed. These nerve paths correspond with the cell neura and the centers with cells located in the cerebro-spinal system. The question arises in the case of a single cell with its branches; such changes take place and such phenomena are manifested under stimulation. It is true that when the cells are grouped together and the neuronic branches are united to form periphreal nerves such stimulation affects the grouped cells. In the single nerve cell nervous impulses enter in a certain direction, although this depends upon stimulation from the nerve cell being stimulated at a certain point, the impulse may travel in two directions instead of one. For example, when an impulse enters a cell in connection with the spinal cord at the ventral root there is no passage of the impulse into the other parts of the cord so that while impulses pass from the nerve fibers to the nerve cells in the cord impulses do not pass in the reverse direction. In the case of the spinal ganglia in the dorsal column we find cells that are dineuric, one branch entering the spinal cord and another extending to the periphery. Normally impulses pass into the peripheral end towards the cord passing into the cord to be distributed by the nerve fibers. If the cord is divided just above the point of entrance of a dorsal root and stimulation is applied, the variation is noticeable on the periphreal side of the spinal ganglia. In this case stimulation is applied to the spinal end of the ganglion cell, the impulse traveling through the one branch of the cell body entering the cord, then through the cell body in the ganglion and into the opposite neuron.

Thus the impulse may pass in either direction in the case of the dineuric cell. This, however, would not take place in the intact cord because the stimulus must be applied to the end of the neuron. In the central nervous system it is supposed that impulses pass by a series of such transmissions, the impulse passing from cell to cell, each cell arousing into activity the neighboring cell. If a cell receives an impulse from one of its neura and then transmits it to another cell through another neuron, these cells must be regarded not simply as paths for the passage of impulses, but as distributors of impulses; in other words, physiologically every cell body is a subsidiary center. In this case the impulse must enter the nerve cell, passing along the neura and entering the cell either through the stem or through part of it. In this way there may be a double pathway along which the impulse may travel in reaching the cell. The impulses thus received must pass out of some of the branches. The question arises whether the branches of the cell are necessary for the reception and transmission of such impulses. In the case of the fish it has been proved that the cells of the spinal cord can pass impulses without any branches developed, indicating that the impulse transmission depends upon the cell condition rather than the development of branches. Thus a modification of the cell wall may take place by which connection for impulses is established between neighboring cells. There is no doubt, however, that where cell branches are developed it is a peculiar function of these branches to form such connections. Thus the cell form, particularly the form of the cell wall and

the development of the branches represent important functions in connection with the receiving and giving out of impulses. Where the branching is complicated there is a capacity on the part of the cell to give and receive numerous stimuli. In the evolution of the cell this is brought up. The primitive cell has no branches. Later we find the neuron and still later the branches, indicating that this branching process goes on to maturity becoming more complicated till perfection is reached. When the impulses reach the cell certain chemical changes take place resulting in the sending out of the impulse from the cell varying according to the changes that have taken place within the cell. This variation is not known except in so far as the strength of the stimulus alters the intensity of the negative variation. If we add the multiplied influences of a vast number of such cells we can form an estimate of the varying intensity of an impulse as it passes along the nerve path. It is estimated that in the case of the nerve cells in the spinal cord impulses are discharged at the rate of ten a second. It has been supposed that a nerve cell may be stimulated at any point although there is no evidence to bear out this point. As the cells lie embedded in the ends of other cell branches it is impossible to say whether the impulse passes directly from cell to cell or through the neura. It is probable that every part of the nerve cell is subject to stimulation and hence possesses irritability. Side by side with irritability as a nervous property, is conductivity, although there are parts of the nerve fibre in which conductivity is present while irritability is absent. If the phrenic nerve is laid open and compressed by the fingers, the diaphragm contracts. After the exhaustion of this part, if nearer the cord the nerve be again compressed diaphragm contraction still follows. Thus after irritability has ceased conductivity still continues active. The same thing is true in the case of degenerated portions of the nerves when passing through regeneration. Although they will not respond to stimulation they will carry stimulation from an irritable part. This indicates the possible presence of conductivity all along the nerve path, both in the cell bodies and their branches. What amount of stimulation is necessary to secure a discharge in the case of a single cell, a single stimulus produces a single impulse. It is probable, however, that to sustain the transmission of impulse there is a summation of stimulations necessary, the discharge taking place in connection with this steady stimulation. The necessity for this continued stimulation may arise from the fact that certain chemical changes take place in connection with the reception and discharge of the impulse by the cell. These chemical processes represent the metabolism of the nerve cell. During the cell katabolism certain substances are found which discharge the energy of the impulse, producing such a change in the walls of the cell that it is possible for osmosis to take place in connection with cell nutrition. In this way the transmission of impulses including the changes that take place in connection with the cells, has an important bearing upon the nutrition of the cell. The changes are most active in connection with the cell as the blood capillaries surround the cells. In regard to the chemical changes

that take place in the cell little is known except that during cell activity the nerve substance becomes less alkaline, at times becoming slightly acid. The passage of nerve impulses is necessary to the preservation of the trophic condition of the cells, for if the cells cease to be active they degenerate. This arises from the fact that by the passage of these impulses certain changes take place that have a trophic influence upon the nerve tissue, and the arrest of these changes leads to an atrophied condition.

This is evident in the case of the amputation of limbs those nerves becoming atrophied that cease to possess functional activity after the removal of the limb. The neuronic portions arising from the cells located in the anterior horns of the spinal cord or in the cells of the spinal cord itself are removed. In the latter case the impulse is prevented from entering because of the interruption of the peripheral portion and in the former case the impulse is prevented from being delivered from the cell by the destruction of the peripheral portion. In the case of the spinal ganglion cells the nerve path by which impulses pass into the ganglia is partially destroyed although some impulses do pass as is manifest from the sensations that are felt even in the case of the amputation of a limb. The spinal cells are thus cut off from one of the pathways of impulse namely those which reach the cord through the posterior roots, although other pathways of stimulation remain. Similarly the efferent nerve path is cut off and certain impulses pass outward to the ends of the amputated limb. These impulses tend to contract the muscles surrounding the stump indicating that the efferent impulses mark the discharge from the cells. Hence the fibers although losing their connection in the amputated limb still retain their activity If the afferent impulses are cut off from a cell or group of cells, then the cells become more or less atrophied by the destruction of these fibers, indicating that the activity of the cells possess nutritive value, and that the different cells physiologically aid in the nutrition of each other. The cells vary much in their power of using the nutriment surrounding them. By experiment in connection with the spinal cord of a cat, it has been found that the artificial stimulation of the cells by electric irritation produces changes in the cell bodies. The prolonged stimulation resulted in a shrinkage of the cells and the flattening of the sheath nuclei, the shrinkage depending upon the time during which stimulation is applied. It has been demonstrated that this change in the cells is physiological as the cat recovered after such changes were produced· By the use of nervous tissue cells of the sympathetic ganglia of frogs it has been demonstrated that these changes take place in the nerve cells in the living subject, the resting condition representing the large spherical form of the cells and the shrunken condition representing the change upon the cells by activity. These changes then take place normally in the human subject, the changes varying according to the degree of stimulation and the amount of nutriment plasma surrounding the cells. Thus there are certain definite changes taking place in the cell bodies in connection with nervous activity, these changes representing the normal passage of impulses through the

cells. In the case of the nerve branches from the cells no such changes as yet have been found to take place.

The entire cell body is subject to the control of the nucleated part, the nucleated part being more important. If a nerve fiber is cut off from the cell body from which it has developed, the fiber will soon degenerate, the degeneration taking place at the same time along the entire fiber. This degeneration consists of degeneration of the axis cylinder which gradually disappears, the medullated part being absorbed leaving the primitive sheath, and the nuclei of the sheath. In the non-medullated fibers degeneration takes place rapidly the changes taking place in the central part of the external portion and the nuclei remaining intact. In the central nervous system the peripheral parts of the fibers which are divided from the cell body degenerate. Thus the nervous system is under the control and dependent for nutrition upon the cell body. Section of the posterior root at the peripheral side of the spinal ganglion in the case of the spinal nerves results in degeneration of all the fibers to the peripheral side of the ganglion. Section of the posterior root on the spinal side of the spinal ganglion causes degeneration of the nerve fiber to the spinal side of the cell body. Section of the anterior root causes degeneration to the peripheral side. In both cases the degeneration takes place on the side away from the cell body. When section of a nerve takes place there is always central degeneration to the next Ranvier node as well as peripheral degeneration. Degeneration on the central side beyond this node depends upon circumstances. If the regeneration is prevented certain changes take place, namely, the cessation of development and the atrophy of the affected part. In the case of the renewal of a limb these changes are noticeable in connection with the cells of the spinal cord. In the case of young animals when nerves are removed from their connection with the spinal system they are severed just at the junction with the spinal system. In this way when afferent nerves are removed atrophy takes place in the cell body in connection with the spine and any of the cell branches within the spine these disappearing entirely. The reason of this is that in growing animals the struggle for existence is so strong that these weakened cells cannot compete with complete cells, the complete cells with their attachments. This has an important bearing upon the human subject as certain injuries during the foetal life affect these bodies preventing development resulting in the abnormal condition of certain parts of the spinal system.

If the severed ends of a divided nerve are brought together the fibres may be completely regenerated. While the dissolution and absorption of the medullary sheath is taking place, the nuclei and the protoplasm in proximity to the nuclei enlarges, forming new substance inside the old sheath. Later there is formed a new sheath over the new substance forming a new fibre on each side of the division, union taking place in this new substance. Around the nuclei of the sheath new parts are formed constituting a new tubular sheath, the new axis cylinder following the formation of this tubular part. The formation of the axis cylinder takes place last in the regeneration process although it is the most important part. The growth of the axis

cylinder takes place from the center and represents the process of formation out from the cell body just as in the embryonic formation of the neuron from the cell. The regenerated fibre at first is small in size, growth taking place gradually in assuming the normal size. Conductivity appears first in the new fibre just as it was the last to disappear, irritability appearing later, indicating that regeneration takes place in distinct stages, the restored function marking those regeneration changes. In the case of degeneration of the posterior roots between the cord and the ganglion, the regeneration taking place from the central end by the growth of the central part, the growth in this case being slow, the sensibility returning before mobility indicating also a difference in the restoration of function. In the case of regeneration of nerves the fibres appear to follow the old curve under the guidance of the old sheath. Attempts have been made to connect the cut ends of distinct nerves, for example, the median and ulnar nerves of a dog the result being a regeneration of the distinct nerves with any lack of coordination. It is impossible to explain this as the different functions of the fibres do not seem to have interfered with sensation and motion although the nerve paths were united crosswise. The question arises can there be the formation of entirely new cells or cell elements in the process of regeneration. There seems to be no evidence of the formation of new cells in connection with the central nervous system, at least in the human subject. Experiments are cited in which in some lower animals new cells have developed although these seem to have developed from embryonic cells. Changes that do arise therefore depend upon the enlargement of the embryonic cells which mark the early stages of growth in the nervous system. A cell if injured or atrophied cannot be replaced by a new cell in the case of the central nervous system.

THE PHYSIOLOGY OF CELL COMBINATION:—The nervous system consists of certain pathways from the external to the internal representing the movement of impulses, these pathways being certain localized centers of activity. The nervous system while consisting of certain paths and centers forms a unit. For arrangement it is usually divided into the central nervous system and the peripheral system. But neither of these divisions is natural being considered simply in their separation for purposes of arrangement. In the nervous system we find three groups of nerve cells.

I. Central cells with their neura lie inside the central system whose function is to receive and distribute the impulses along the nerve paths.

II. Afferent nerve cells along which impulses pass from peripheral portions to the central nervous systems.

III. Efferent nerve cells representing the cell branches that pass from the cell bodies inside the central system to the different parts of the body. The spinal cord consists of nerve centers and nerve fibres and represents a collection of reflex centers and a transmitter of nervous impulses. The spinal cord conveys impressions in two directions by the afferent paths which enter the cord by the posterior roots of the spinal nerve. The impulses almost immediately pass over to the opposite side of the cord and pass upwards. Hence section of one half

of the cord produces loss of sensation on the other side of the body in the area supplied below the line of section. Impulses travel downward in the antero-lateral column and then pass outwards along the anterior roots of the nerves on the same side. Hence section of one half of the cord produces muscular paralysis on the same side of the body over the area supplied below the line of section. In this latter case there are two classes of efferent cells, (1) those whose cell bodies lie inside the central spinal system the branches representing the anterior spinal roots and (2) those whose cell bodies lie in peripheral ganglia outside the central nervous system. The central nervous system represents the large mass by bulk of the nervous system, and also a much greater number of cell bodies. Thus the cell element in the central system is the most important representing the function of distribution and reception. In the early embryonic stages the cells have no connection being at first isolated from each other and later forming branches by which are developed their connections. In development this connection becomes fully established by means of the neuronic and minute cell branches. In the cells of the cortex for example, the branches gradually increase in number representing the evolution from the lower to the higher vertebrates. These increasing branches increase the size of the cortex substance having an important functional bearing upon nutrition and also increasing the capacity of renewing impulses. In the case of the central cells we find a great variation in the number of branches being very numerous in the cells of the cortex and very few in number in the posterior horns of the gray matter. Each cell is independent in formation, the outgrowth from the cell representing the neura and the minute branches. In the human subject cell communication seems to be established in the case of the central system by means of cell contact and not by the union of the cell branches of the different cells. In the case of the cells of Purkinge in the cerebellar cortex the cells are found to terminate in the basket shaped neura of the pyramidal cells, in this case the connection taking place between the cell body and the neuron. The passage of impulses will depend upon chemical changes taking place in the connecting points of the branches, these changes taking place slowly. When an impulse is brought to the spinal cord through the posterior roots it is received in the cells in which the neura terminate. When the afferent neuron enters the cord it divides into two branches, the short one passing towards the periphery of the cord and the large one towards the brain. These branches are connected with the spinal cells by means of subordinate branches. These central cells form series through which impulses are transmitted. Along the length of the cord there are 31 afferent roots on each side, there being an efferent root anterior corresponding with each posterior root. In this way the whole length of the cord is divided into homologous segments. In the case of the afferent fibers they enter into the cord and are not limited to any definite segment area as are the efferent roots these springing immediately from the cell bodies in the segment of origin. This

segment division of cells is not so complete however in the human subject as in some of the lower vertebrates. In this way we have a bilateral symmetery more or less perfect in the nervous arrangement of the cord and the afferent and efferent fibers. Throughout the entire central system we 0nd neuronic branches crossing from one side to the other slde as in the intersection of the pyramidal fibers and in the posterior commissure of the spinal cord. This may be effected in the cells of the central system either by the neuronic or the subsidiary branches of the cell bodies. Impulses are supposed to originate at the periphery, although the spinal cord is not merely engaged in the transmission of impulses, the nerve centers it contains being capable of originating nervous impressions under the influence however of afferent stimuli. Thus it is necessary to have an external stimulus in connection with an end plate organ. During normal life stimulation is constantly taking place so that the nervous system is constantly subject to the stimuli that produces changes varying with the variations in the stimuli and also with the chemical changes in the cell bodies. If the stimulus imparted to the nerve in the form of an impulse travels through a single nerve fiber the impulse will vary directly with the stimulus in strength. If one cell impulse arouses another cell impulse there is a variation in the impulse due to the changes taking place in connection with the transmission of the impulse. In this way the impulse is passed along the central nervous system with a diminished intensity, this diminuition taking place in connection with the minute branching of the cell branches. Thus impulses passing into the central nervous system are distributed and also then become weakened, until terminating in an efferent cell the impulse is discharged along an afferent path. The impulse in its passage thus reaches a large number of cells and it is discharged from these cells in its transmissions. The nervous system is then kept in a constant state of stimulation so that impulses reaching the central system affect it with varying degrees of intensity in their variation depend upon the fibers and their cell connections and also upon the physiological and chemical condition of the cells.

This physiolological and chemical condition may be influenced by the use of drugs.

The diffusion of the efferent impulses depends upon the cell arrangement. When the impulses are sent out from the cells they pass out of the cord by the anterior roots, although they may pass from the lateral and dorsal roots. The impulses thus sent out from the cells along the neuronic branches (1) may be distributed to the muscle fibres. In this case there is simply distribution of the impulses to the region controlled by the fibres. (2) These impulses may pass to the sympathetic ganglia. The sympathetic system, including the ganglia and plexuses, are connected with the efferent branches from the central nervous system. In the sympathetic system we find mono-neuric nerve cell bodies, with or without dendronic branches. After leaving the spinal cord by the efferent neura we find the ganglia in which there is a group of nerve cells, the neura for these cell bodies passing out towards the nerve plexuses. In the

ganglia we find a number of cell bodies, larger in number than the neura from the spinal cord, thus increasing the nerve path towards the peripheral plexuses. Thus we have certain fibres originating in the spinal cells and others originating in the spinal ganglia passing out to the periphery. The former fibres are intercepted in the ganglia and are medullated, originating from the first thoracic to the fifth lumbar. The fibres originating in the ganglia are mostly non-medullated. The cells in the ganglion are not connected together although various fibres enter into the cells from the spinal cord cells. When the neuronic branches pass from the ganglia towards the peripheral plexuses they form a great number of branches representing the diffusion of the impulses.

Normally the striated and unstriated muscle tissues are in a condition of tonic contraction. If the nerves supplying the muscle tissues are cut, the tonic contraction gives place to relaxation. If the cord be extirpated the efferent impulses that keep the muscle in a state of tonic contraction are destroyed, the muscles becoming relaxed. The difference in the degree in the impulses represents the difference in the conditions of the muscles found, for example, in those who exercise the muscles as compared with those who take no exercise. In the case of insanity the tonic contraction of the muscles is, to a large extent, lost, depending upon the loss of nutritive elements in connection with the central nervous system. It is this that gives the maniac those characteristic facial and muscular expressions that represent want of activity and are called expressionless. In cases of violent insanity the changes from the one condition to the other represent marked changes in the nervous impulses transmitted from the ventral system to the muscles. Even in the final struggle of life represented in death we find the nerve tissue undergoing a chemical change originating impulses which after passing to the sensory fibres produce the characteristic rigor mortis or cadaveric condition. If an animal is suddenly killed and if one sciatic nerve be cut at once the rigor mortis will begin very much sooner in the leg in which the sciatic is intact, indicating that the nerve connections with impulses passing along these nerve paths modifies the after death condition. Thus we find afferent or sensory nerves representing varying impulses passing into the central nervous system from the sensory system. These impulses arouse a response which takes place through efferent cells, the response representing impulses emanating from the central nervous system to be diffused among the ganglia, plexuses, and finally along the muscles and secretory tissues. The afferent impulses are limited to the single pathways represented by the single cells whereas the efferent impulses in passing to the sympathetic system have an enlarged pathway representing large diffusion. The great question that arises then is the question of the passage from afferent to efferent cells in connection with the central nervous system. Here the main problem is that of the distinction between a voluntary and a reflex action. Reflex action in the case of the transfer of afferent to efferent involves the absence of consciousness, the action being dependent entirely upon physiological conditions and relations. If the

spinal cord be cut just below the medulla so as to cut off all the upper portion of the central system, the animal will be in a collapsed condition. On dissection of the animal the efferent fibers from the cuteaneous surface, the spinal cord and the spinal nerves passing from the end by the posterior roots would be found intact. Hence we have the mechanism of reflex action namely an afferent path, nerve cells in the cord forming the receiving and distributing center and an efferent path for the passage out of impulses. If the cutaneous nerves be irritated muscle contraction would follow, the muscles contracting following the segmentary arrangement of the cord according to which they are supplied with nervous branches. The muscle contraction depends upon the strength of the stimulation as well as the length of the continuation of the stimulation and the number of muscles that are supplied with nerve connection from the same cell area. Normally the contraction represents not spasmodic actions but coordinated movements. The response in the contraction of the muscles may continue if there is sufficient chemical change in the cell or cells along the path of impulse, the chief changes taking place in the central cells. After the stimulus is applied there is a latent period during which there is no response given, after the latent period the response being given in the muscle contraction. If the stimuli are increased so that there are a number of single stimuli the response is the result of the summation of these stimuli, the impulses being collected at some point until there is sufficient force to discharge an impulse along the efferent path. This summation takes place either in the nerve cells themselves or else in connection with the afferent fibers with these nerve cells. The various segments of the cord have independent functional activity in the control of certain regions, the connecting of these segments representing the co-ordination of impulses as to time and degree of stimulation. These are constantly passing out to the muscles and secreting glands efferent impulses, the impulses depending upon the strength and character of the afferent impulses. The impulses that pass to the cord upon stimulation of the afferent paths pass through varying changes before being redistributed and transmitted outwards, indicating that the cells receive and then arrange for the distribution of these impulses. This may be due to the fact that impulses are not distributed in the same way in the different cells or it may be due to the difference in the matter of responsiveness in the efferent cells.

Some physiologists have spoken of selective affinity with the central cells, alleging that these cells are capable of choice in the matter of the distribution of impulses. This so called psychic element however in the central cells seems to follow physiological rather than psychic conditions. The difference as we have said in the reaction is due to the extent of the stimulation, its intensity and also in a large measure to the condition of the central nervous system. In the human subject the separation of the cord from the central nervons system results in rapid death. There are however cases in which pathological conditions have practically cut off the spinal cord from the nervous system, in connection with

which reflexes have been noticed. In the human subject reflex reactions are found chiefly in connection with the secreting glands and the unstriated muscle tissues of deglution, defecation etc. It is to be noted that reflex actions may come to be under the control of the will, changes taking place probably in connection with the development of neuronic branches from the cephalic cells into the spinal cord. In this way nutrition and defaecation as well as respira- and even the heart pulsation can be controlled by the will. The same thing is true of certain reflex actions that disappear with the development from immaturity, for example, the case of sucking in a child. A definite amount of activity in case of the cell is necessary to sustain its normal condition, this activity being the basis of the cell nutrition. If the activity is diminished then the power of response becomes also diminished. It is said that to dip a frog in cocaine solution deprives the central system of the power to respond to a stimulus to such an extent that even sensory impressions call forth no response. Thus the activity of the cell substance is the basis of its capacity for receiving and distributing impulses.

A voluntary action as distinguished from a reflex one implies the freedom of the will to change the response, not only in the form which is assumed by the response, but also in the time at which the response is given. Here consciousness or the physiological element enters in to vary the physiological development, in order to carry out the complex voluntary actions, the whole nervous system is called into action, especially the upper part of the brain in which are localized the higher centers. Reflex actions may take place with afferent or efferent fibres and the small segment of the spinal cord, whereas voluntary actions involve a wider path, taking in the afferent system together with the spinal cord and the cephalic cells, and also the efferent system under the control of a large number of cells. In the human subject the posterior root fibres enter the cord in three groups—the median, intermediate, and lateral groups. If the posterior root is divided on the spinal side of the spinal ganglion, all these fibres degenerate. This degeneration is found to reach down along the dorsal column a short distance and up the dorsal column as far as the lower part of the medullary region where the dorsal nuclei are located. This means that all along the spinal cord we find dorsal fibres running the length of the cord at the same time that we find collateral branches which are distributed at different points along the dorsal column, these fibres being continuous with those found in connection with the horns. If the spinal cord is divided on one half the fibres degenerate on the side of the section, although fibres also degenerate on the other side, these fibres representing the afferent nerve paths. These impulses entering the cord from the posterior roots may pass along the nerve fibres representing the continuation of these afferent fibres, or they may pass through the central cells and in some cases to the other side. The lateral columns of the spinal cord represent the afferent paths for impulses involving motion and sensation on the peripheral side of the section. The question arises whether the posterior fibres from the cord represent all the sensations of heat, cold, pain, etc. It

has been estimated by Stilling that there are 500,000 posterior root fibres indicating the adequate nerve supply for the muscle and cutaneous tissue. The skin is not evenly supplied with nerves as it is stated that the skin of the arm is much more plentifully supplied with nerves than the leg. The afferent fibres that collect and carry the cutaneous impressions are developments of the spinal ganglion cells. The sensation of heat, cold, compression, including pain, are said to be represented by special nerves. It is supposed that in all these sensations if these sensations are extremes there is pain that is when the stimulation is normal the ordinary sensations of cold and heat and pressure result while excessive stimulation results in pain, the sensation of pain including the other normal sensations. Thus pain depends not upon the existence of special sensory nerves but upon the intensity of the stimulus, or the extent of the nerve surface that is included in the stimulation.

This means that a phsiological analysis of pain gives as excessive excitation including the conveyance of abnormal impulses to the central system and an abnormal discharge of those impulses from the central system, these excessive impulses destroy the co-ordinated reactions of the muscles producing intermittent actions such as we find associated with painful sensations. It is said that the different branches of the cutaneous nerves are susceptible of different sensations, accounting for the difference in the case of applications of different stimuli. electrical, mechanical or thermal, different sensations resulting from these impulses passed to the centers. Some physiologists claim that the difference in the sensation depends not upon the nature of the stimulus but upon the character of the cells in the central system. It is more probable however that a difference of stimulus affecting different nerve fibres lead to different nerve impulses carried to the central cells.

The question of the distribution of impulses among the efferent paths and as to the passage of the impulses associated with heat, cold and pressure. In the human subject it would seem that if there is an injury to the one lateral portion of the spinal cord it is accompanied by either the loss or the diminution to a greater or a lesser extent of the sensations. Man seems to differ from the lower animals as in these the half section of the cord seems only to have a temporary effect. In one case we find that where the one lateral half was injured and also the gray matter of the anterior and posterior horns the tactile sensation was not interfered with although the pain sensation was lost on the opposite side. It has been inferred from this that the sensation of pain after entering the cord crosses to the opposite side and passes to the brain along a dorsal column. Thus the dorsal and lateral columns seem to represent the afferent path for the impulses from the sensory nerves. These pathways are associated with the neuclei of Gall and Burdach on the same side. The neurons from these cells pass toward the brain intersecting each other in passing across the cord passing to the cortex cerebri either directly or through the alanius, indicating that the impulses have crossed in their connection with the cerebellum and cerebrum. As the impulses pass up we meet with the

cranial nerves. The lateral nucleus of the alanius is associated with the cortex cerebri of the same side. In the case of the olfactors the impulses pass to the olfactory bulb on the same side passing through the olfactory region to the anterior perforation, one part of the tract leading into the gyrus fornicatus and the other into the gyrus hippocampi. The afferent impulses therefore pass through the internal capsule to the cortex cerebri, all or nearly all of them passing through the alanius, except those reaching the cerebral hemisphere through the olfactory tract. Impulses coming in from the afferent nerves reach the cortex cerebri this way being fully developed in the higher animals. In the case of rabbits and dogs electric stimulation has been applied to the opened surface of the cerebral hemisphere. If a weak current is applied for a few seconds slight movements of the muscles are noticeable, the contraction continuing for a short time after the withdrawal of the stimulation. If the current is increased in strength a great number of muscles respond by contracting, sometimes producing convulsive movements. Very soon the response ceases to be given, indicating the loss of irritability. The area represented by the organs of vision is the only one that can be definitely localized in connection with stimulation. When the rest of the area is stimulated certain movements follow, these responsive movements having been made the basis of the localization of the sensory centers. If stimulation is applied to the posterior parts of the visual region the eye turns down, and if stimulation is applied to the anterior parts the eye turns upward, the movements taking place in the two eyes even though stimulation is applied only to one side. In connection with the other sensory areas similar results are received indicating (1) the existence of cells where stimulation produces certain muscular contractions; (2) that these cells while capable of receiving impressions from the sensory organs are also capable of stimulation from the cell itself. By the use of electrical stimulations applied to the different regions of these sense areas localizations have taken place in connection with the different senses and also with different sensations. The hemisphere may thus be divided up into areas and sub-areas corresponding with the different parts of the body, the arms, legs etc. These areas may be also distinctly separated from one another as centers in which we have combination of cells controlling the different parts of the organs of the body. This is identified with the motor regions which control the various bodily movements. In the same area we may also localize the characteristic kinds of movement, such as extension and bending of the arms or legs. This division into centers may be carefully made by separating the small areas from each other by means of incisions so as to separate all other influences from the contiguous areas. By making an incision parallel with the surface beneath the cortex it will be found that stimulation gives no response, indicating that the impulses arising from stimulation pass from the cortical portion into the substance thus entering into the nerve path along which the impulses pass. If this portion of the cortex is removed and stimulation is applied to the substance of the hemisphere a simi-

lar result will be received, except that the response in the case of muscle contraction is less co-ordinated and continues only while the stimulation lasts. Thus the stimulation of the cortex affects the cells, impulses being aroused which pass from the cells to the fibers and thence to the muscles. If the part of the cortex is removed from the motor region there is found degeneration in connection with the internal capsule and also in the substance uniting the hemispheres, the degeneration taking place upon the same side and also in the fibers that cross the callosum to the other side. This gives us the difference between the part which crosses and which is not crossed representing the cross and the direct pyramidal areas. The direct pyramidal tract disappears in the spinal cord entering by the anterior commissure. The cross pyramidal tracts are said to end in the cord in the cervical and lumbar expansions. Sherrington observed that in the case of a mulateral injury of the cortex there is degeneration in the two crossed pyramidal tracts, the degeneration being greatest at the point of these two expansions of the same side as the injury. He inferred that the fibers of the pyramidal tract recross in the spinal cord, there being two groups of fibers, the one group crossing and the other not crossing so that the two groups of fibers are found in the two sides of the cord. If this is true then we have a basis for the capacity for each cerebral hemisphere to control the body movements on both sides. As this degeneration is continuous it seems also to indicate that the cortical cells have neurons reaching into the cell regions of the spinal cord, the different neura extending to the cervical and the lumbar enlargements of the cord. If the spinal cord is divided midway in the dorsal region and the ligoranum region area is stimulated by the stimulation of the divided cord, in the former case we find impulses and in the latter none, because in the former case stimulation is applied to nerves that are passing to the lumbar region whereas in the latter case the neura from the arm cells ends in the cells of the cord nearer the brain than the divided part of the cord. Thus the cell neura in the cortex extends to the cord regions that control the movements of the arms, legs, muscles. These neura of the cortical cells are contained wholly inside the central nervous system carrying impulses along the cord for distribution in the different cord regions, representing the combination of the axial cells. In this way we have the connection established between the cortical cells and the cord cells. Thus the cortical area represents the areas of movement, the size of the area having no relation to the muscle movement controlled. In the human subject as well as in all the higher animals this area separation seems to be most complete, the separation being studied in connection with the monkeys. The chief location if these areas is found in the two central convolutions of the brain these areas going beyond only along the great longitudinal fissure. The cortex according to Munk is divided into areas in which are found the terminals of the afferent nerves indicating the area connected with the sense organs and also the muscles, the latter including the sensations aroused in connection with the skin. In this way the whole of the cortex in which localized areas are found consists of cells and fibers carrying impulses to

these cells, the cells undergoing certain changes resulting in the passage of impulses to other portions of the cortex and to the central nervous system. There is a controlling of certain different cell groups in the cortex exercised over the same cell groups in the axial system of the spinal cord, as for example where movements of the eye follow not only stimulation of the eye area but also of the parts of occipital cortex. If the stimulation of the cortex cerebri produces a response simply on the one side that response is found in the side opposite to the one stimulated unless in cases of the symmetrical muscles as in the case of the eyes, the contraction of the muscles taking place simultaneously. The impulses leaving the cortex pass along the pyramidal tracts to the cells of the spinal cord, in the case of the human subject there is a large number of fibers representing the active operation of this cortical region and its close connection with the spinal cord. It is from this region that disturbances arising from the removal of the brain in the human subject produce reactions upon the entire nervous system, the connection being so close that great disturbances follows. In regard to the sensory areas, these have been localized chiefly in connection with brain anatomy and the brain injuries whether congenital or otherwise. The olfactory center is localized at the point of the temporal lobe in close connection with convolution Hippocampi. The auditory region is said to be localized in the first and second temporal convolutions as injury to these produces deafness and their destruction results in the complete deafness of the opposite ear. The visual is associated in some way with the cuneate lobule as the injury of this region affects the sight. If there is a lesion in the visual region of one hemisphere there is a partial affection of sight in both eyes. In the case of the visual and auditory regions, if the areas are removed, stimulation of the subcortical substance does not give any response. Thus the central cells must be in the cortex and if the impulses are not passed to these cells then they do not call forth any response from the center. Although the impulses from the cortex control certain organs of the body the fibres of the cortex are so associated together that the stimulus of one region may result in the motor impulse passing to another region and from that region to the appropriate organ. These fibres connect any of the lateral areas on the same side throughout the central nervous system. For example, the stimulation of the visual region may result in the transfer of impulses to the hand region. Broca pointed out that when a lesion is found in the third frontal convolution of the left hemisphere there is a loss of speech. Hence he localized the speech center in this part of the cortex. This does not involve the inaction of the muscles of speech probably on account of the fact that in this area there are found no cells which are immediately connected with the nuclei that govern the muscles of speech. The corresponding portions in the right hemisphere have nothing to do with the production of speech. From what we have seen it would seem that the sensory impulses are distributed in different cells among the different areas, these impulses being sent from the sensory to the motor regions by means of neura connecting the two regions, the

short tracts being found in the cortex and the larger tracts in the deeper surface. There seems to be no uniform relation between the connecting tracts in the different areas and there is not symmetry in this connection as between the two hemispheres. It seems that in the case of a right handed person the lesion in the left hemisphere is more hurtful than one in the right. The lesion in the left seems to be more frequent and to have a greater effect. The connections with the sense organs at least the eye and ear and speech seem to be more perfect in the left than in the right. This implies more perfect differentiation of the impulses in the left hemisphere, because these impulses can reach the motor regions of the left with greater ease than the right. As yet there is little evidence that the reverse is true in the case of left handed persons. If one hemisphere is damaged in the mature individual there follows a decrease or loss of function, although this may be temporary if the person is immature, in which case the other hemisphere seems to be capable of performing the function of the other. The nerve cell whose neuron is found in the pyramidal tract must therefore be the medium of a great number of impressions. If this cell is injured then the capacity of receiving or giving out impulses is modified or destroyed resulting in the loss of function in the part controlled. The relation of certain areas, for example of the sense organs, is said to be proved by the fact that a complexity of impressions followed by their sensations is necessary in order to bring the areas into activity, the response being given in the case of one or more of these organs. Differences also exist among individuals in the capacity of discernment especially in the case of minute differences, even with the same sense organs. The minuteness of this capacity of discernment does not depend upon training, at least not entirely, the difference being found in the cells and the fibres representing the pathway of impulses to and from these cells. The visual cells seem to be more acute on account of their more perfect development and organization. The same thing is true of the capacity for expression as between the power of speech and the power of handwriting.

In the spinal cord we find the white and the gray matter, the white substance surrounding the gray matter. Anteriorly the cord is divided by the anterior longitudinal fissure into a right and a left half and posteriorly by the posterior longitudinal fissure. Each lateral half is divided into columns by a furrow at the point of origin of the anterior roots. In this way we have three columns, the anterior, posterior and middle. In the lower cervical and the upper thoracic regions each of the posterior columns is divided into an inner and outer column. In the gray matter we find two lateral columns united by a commissure each half representing a round anterior horn and a pointed posterior horn. Laterally the anterior horn shows another called the lateral horn, especially in the lower cervical region. In the cervical and lumbar regions the gray matter is more abundant. The white matter consists of medullated fibers of varying size, while in the gray matter we find both cells and fibers, the cells being multipolar, the polar neurons forming axis cylinders for the medullated fibers. These elements

of the cord are bound together by connective tissue processes and the neuroglia. The neuroglia consists of a semi-fluid substance together with the cells. The nerve cells are found in groups arranged in symmetrical form in the ganglionic columns of the gray matter. These cells consists of (1) those in the anterior cornua whose neura are continuous with the fibers of the anterior roots. This is called the motor ganglionic column; (2) a column of small cells in the middle portion of the cord from the third lumbar to the seventh cervical called the posterior vesicular column, the neura of which are continuous with the fibers of the lateral column; (3) a column of cells in the external part of the gray matter called the intermediate lateral column. Gaskell says that the cells of the posterior vesicular column give rise to the inhibitory fibers of the alimentary vascular and glandular systems. The vaso-constrictors arise only in the dorsal region. The motor fibers of the alimentary muscles originate at the base of the posterior horn whereas the motor fibers of the diaphragm, abdominal muscles, of the mouth arise from the dorsal side of the intermediate lateral column, and the motor fibers of the vascular and glandular organs from the small cells of the same column. The primitive cord consists wholly of gray matter the columns being added later. Along the sides of the spinal cord are the attachments of the anterior and posterior roots of the spinal nerves, some nerves from the anterior roots, terminating in cells in the anterior horn, others crossing to the opposite side of the cord while others pass to the anterior portion of the lateral column and the posterior horn. The function of the spinal cord is threefold:

1. To transmit impulse, both motor and sensory. The spinal nerves have two root connections with the cord, the anterior and the posterior. If a number of anterior roots are divided there results on the same side of the body paralysis of the muscles of motion. If the divided nerves are stimulated at the periphral ends the muscles may be thrown into a tetanic state. No effect is produced upon sensation indicating that these anterior roots are motor nerves. If the posterior roots are divided sensation is lost on the same side of the body and if the central ends of the divided nerves are stimulated the sensations become painful, indicating that the posterior roots are sensory nerves. If an incision is made so as to separate the anterior columns leaving the posterior columns solid there are no voluntary movements in the parts below the division. If an incision is made so as to sever the posterior column leaving solid the anterior, voluntary movement is weakened but not lost. If an anterior lateral column is divided voluntary movement is lost on the same side. This indicates that the motor fibers pass along the antero-lateral column from the brain and that these motor fibers pass to the same side of the body. If the posterior column is completely severed sensation still continues in the lower parts beneath the section although the co-ordination of movements is lost. If both the antero-lateral and posterior columns are divided it does not destroy sensibility, if however the posterior column alone is left intact sensibility disappears indicating the passage of sensory impulses brought to the

gray matter. This is explained by the fact that the nerve fibers intersect each other in the gray matter. Brown-Sequard has shown that semi-section of the cord cutting into the gray matter weakens sensibility on the opposite side. The impressions produced in connection with touch seems to travel along the posterior columns. Where there is paralysis of these posterior columns the sense of touch is lost although the feeling of pain is not lost. In locomotor ataxia the first stage represents an interference with sensibility accompanied by darting pains in the back and limbs. This is followed by want of power to control the body including the loss of co-ordination including the loss of muscular sense. The final stage is represented by total paralysis. This is caused by a chronic inflammation in the region where the posterior roots join the cord and in duration of the posterior columns, finally affecting the whole cord. This indicates that the sensory pathway is through the posterior columns.

2. The spinal cord acts as a reflex center. We find reflex centers of movement in the cervical, dorsal and lumbar areas of the cord, the higher cervical region being associated with special activity. Stimulation may originate in any of the afferent nerves, the impulse passing to the cord and producing changes in the cells in the gray matter and resulting in the sending out of impulses through the motor fibres. This reflex action represents co-ordination between afferent nerves and muscular regions of the body. Reflex activity may be inhibited from the upper centers, hence the removal of the upper part of the brain. This increases the power of reflex stimulation. The same effect may be produced by strychnine and opium and opposite effects by aconite, chloral and ether. Special reflex centers have been localized in the cord. A spinal center from the cilium connected with the iris movement between the 6th cervical and the 3d thoracic nerves. Stimulation of this area results in pupil distension. Accelerating centers are found in connection with the sympathetics, the stimulation of which increases the heart's action. Respiratory centers governing the reflex actions of the thoracic and abdominal muscles. There are also centers in connection with the limbs, both upper and lower. In the higher part of the lumbar region there is an erectile center connected with the organs of generation. Centers associated with the action of the spinchter ani and the bladder are found in the lower dorsal and upper lumbar regions, the destruction of these involving paralysis of the bladder and the sphinchter ani. Perspiration centers and vaso-motor centers exist in different parts of the spinal cord.

3. The spinal cord also acts as a center for trophic influence. In the anterior horn are cells which have a trophic relation to the muscles. When these cells atrophy or degenerate the muscles become soft. It is claimed by some that the cells in the posterior vesicular column are trophic in their influence upon the visceral organs. These cells are different from the other cells of the cord, being bipolar, these cells being found only where the nerves leave the cord and control the viscera. This indicates there are trophic cells to the viscera.

In the medulla we find a more complex arrangement depending upon the nerve

fibres that pass through the gray matter and also the nuclei representing the new gray matter. It is the extension into the brain of the spinal cord connecting the brain proper and the cord. The spinal column is connected with the cerebrum and cerebellum by means of the medulla. The gray matter of the medulla, instead of presenting the appearance of the cord, is varied by the nuclei of the white matter, these nuclei being connected with the cranial nerve roots. These nuclei correspond with the following nerves:

1. A nucleus for the hypoglossal, the motor tongue fibre.

2. A nucleus for the auditory nerve.

3. A general nucleus for the spinal accessory, pneumogastrics and glossopharyngeal nerves.

4. A nucleus for the 4th to the superior oblique muscle of the eye.

5. Neucleus for the facial motor nerve.

6. The neuclei for the 6th to the external rectus muscle of the eye.

The function of the medulla may be summarized:

1. In connection with sensory and motor impulses. It the medulla is destroyed death will result because of the close relation of the medulla to circulation, respiration and vaso-motor activity. The motor nerves from the brain interlace in the anterior pyramidal tracts passing down the lateral column of the cord through the anterior roots of the spinal nerves to the muscles. If the anterior pyramid is divided above the interlacing fibers paralysis results on the opposite side. Sensory fibers also interlace in the gray matter. Hence a blood clot in the brain in the left corpora striatum and the alanus opticus produces paralysis on the opposite side, that is, in this case right side hemplegia.

2. The medulla is the seat of reflex action. Various centers are localized in the medulla, the respiratory center in connection with the pneumogastrics, consisting of an inspiratory and an expiratory part; the vaso motor center; the cardiac centers, an accelerator associated with the sympathetic and an inhibitory connected with the vagus; the deglutition center; the vocal center; the glycogenic center in connection with the vaso-motor action upon the liver; the salivary center controling the facial including the chorda tympani and the superficial petrosal; the center controlling the facial muscles through the 7th and mastication through the motor fibres of the 5th.

In the cerebrum and the cerebellum we find an entirely different arragement of of the gray and white matter, although the structure is eventually the same The gray matter found in the cortex cerebrium is an enlagement that covers the whole upper surface of the cerebellum, the corpora striata, corpora quadrigemina and the alana optici forming nuclei in the internal portions of the cerebral ganglia; in the central gray matter of the cord and the anterior of the ventricles of the brain out of which the cerebral nerves primarially arise; and in the cortex of the cerebellum. These masses of gray matter cells are united together by white fibrous tissue. The pons varolii is above and anterior to the medulla between the cerebellar hemispheres and forming the lateral peduncles of the cerebellum. We find a number of fibres:

I. An anterior fasiculus continuing from the motor cortical regions of the brain through the crural fibres and also

continuous with the superficial part of the anterior pyramids of the medulla and with the crossed pyramidal region to the opposite side of the cord.

II. Two middle fasciculi, the one continuous with the frontal cerebral lobes through the crural fascicules and the other having fibres from the external portion of the crus.

III. There is a posterior fasciculus continuing from the columns of Turck passing from the same side of the cord.

IV. There are commissural fibres crossing from one side of the cerebellum to the other.

V. A posterior fasciculus containing sensory fibres to the cerebrum from the medulla. Associated with these fibrers are nuelei representing the facial nerve, the motor and sensory nuclei of the 5th nerve, three nuclei of the auditory nerve and the nuclei of the sixth nerve. In function the pons varolii is a reflex center and also the medium of impulses. The motor channel is in the anterior portion. Motor fibres connected with the facial muscles decussate in the pons bearing impressions outwards. If the lower portion of the pons is injured on the one side there is paralysis of the face on the same side and of the limbs on the opposite side. Only rarely is there loss of sensibility and then it is on the opposite side. There are numerous reflex centers associated with the pons. The crura cerebri consists mainly of motor and sensory fibres between the cerebrum and the cerebellum and also between the basal ganglia and the pons and medulla. The only thing known definitely as to the crural functions is that they are a medium for impulses. Irritation of the crura produces painful sensations and the destruction of one of the crura produces circular movements of the body, indicating that the crura are connected with maintaining the steady vertical equilibrium.

THE CEREBRAL GANGLIA:—We find in these the corpora quadrigemina, the thalami optici and the corpora striata, these ganglia all acting with the cerebral hemispheres. The corpora quadrigemina represent two pairs of round bodies behind the thalami optici above the Sylvian aqueduct and closely connected with the crura. In these bodies we find gray matter overlaid with a layer of white matter. The posterior bodies are united to the cerebellum by the superior crura cerebelli and also the crura cerbri by the protuberances on the sides of the crura. The anterior and posterior bodies are related to the optic regions and also the thalami optici. From this it is evident that the corpora quadrigemnia are connected with the sense of vision. If they are destroyed blindness results. If the whole of the brain except these bodies is removed in an animal there is still the normal contraction. If one of these bodies is then removed mobility is destroyed in the iris. Hence these bodies are said to contain the center to which impressions travelling along the optic nerve are conveyed. We find fibres in the 3d cranial nerve that control the contraction of the pupil of the eye and also the cilium which regulates the variations of sight distance. This 3rd nerve arises in the gray matter on the floor of the Slyvian aqueduct contiguous to the corpora quadrigemina. Hence it is said that there is a center of reflex action in connection with the iris and the cilium. When the retina receives a light impression the optic nerve is stimulated and

an impression passes to these bodies. When an impression reaches the center it causes its activity, and impressions may be sent out of the center in one of two directions; (1) upward to certain nerve cells in the gray matter of the hemisphere and as a result from the stimulation of these a visual sensation may be produced or (2) the center in the corpora quadrigemnia may act merely as a reflex center transmitting impressions to the various muscles and so leading to certain movements. This latter condition is said to exist in a state of sonambulism. These bodies are considered to be concerned chiefly in the consciousness of color and of light.

THE OPTICI THLAMI:—These represent the ganglionic groups behind the corpora striata. The internal surfaces are seen in connection with the 3rd ventricle, the external being connected with other portions of the brain. Fibres from the crus cerebri are found in the under surface, the upper surface being overlaid with fibres that pass between the thalamus and the corpora striatum constituting the internal capsule. The fibres which come from the thalamus to the capsule pass to surface of the cerebral hemispheres. In the substance of the thalamus we find cells whose relations are yet unknown. The functions of the thalami are obscure, although they are generally regarded as centers of impulses which when received are sent forward to the corpora striata, or higher up to the cerebral hemispheres. It is supposed that these movements of impulses represent unconscious and entirely reflex actions. The most commonly accepted theory of the function of the thalami is that they represent centers of tactile sensations in connection with sensory impressions on the surfaces of the body, that is, the corpora quadrigemnia and the thalami optici would be the centers of the sense of vision and touch on the basis of space, by means of which sensations are localized in space. The close connection of these two regions would also seem to indicate the close relation of space perception from the standpoint of vision and touch. In apoplectic cases involving the thalami we find interference with sensory activity on the side of the injury. This has lead to the conclusion that they represent the higher ganglia through which all sensory impulses pass and in which they are coordinated prior to their passage to the cerebral hemispheres. Thus they are secondary intermediate centers between the sensory and cerebral centers.

CORPORA STRIATA:—These are on the front of the thalami optici. The larger portion of these is found embedded in the white substance of the hemispheres. The fibres from the thalamus establish a posterior connection with the corpus striatum while the inferior portion is connected with the pyramidal part of the medulla through the internal capsule. In the corpus striatum we find a co-ordinating center of motor impressions. They are certainly engaged in the transmission of impressions received from the cerebral cortex, some say from the thalamus opticus to the muscles. If there is a blood clot in the left corpus striatum there is a motor paralysis of the right side of the body, the paralysis affecting the muscles according to the extent of the clot. If the two corpora are destroyed voluntary movement is destroyed. If the nucleus of the intra-ventricular portion is destroyed progressive move-

ments are impossible. If the nucleus of the intra-ventricular portion is destroyed unconsciousness results. Lesion of the corpus striatum thus produces paralysis, that is, motor impressions originating in the voluntary centers on the surface of the hemispheres are no longer able to reach the muscles and arouse muscle activity as the motor tract decussates at the anterior pyramids. From this it follows that the paralysis will always be on the side opposite to the lesion in the corpus.

A voluntary impulse passes from the cerebrum to the crus and pons varolii of the same side. From this the fibres decussate in the anterior pyramidal area passing down the opposite side of the cord, some of the fibres passing down the same side and decussating farther down the cord, completing the decussation of all the motor fibres before their passage from the anterior roots. The sensory impressions originating on the surface of the body pass to the cord through the posterior roots, going up along the same side of the cord for a distance then entering the gray matter of the posterior horn, passing from cell to cell and upwards along the posterior columns. They enter the pons varolii where the fibers decussate and enter the brain on the other side from which they originated. From this point decussation again takes place in the case of some of the fibres. When they reach the brain, sensory impressions are received in the opposite side from that on which they entered.

THE CEREBELLUM: The cerebellum has three crura, the superior, middle and inferior, which pass into the cerebellum at its front part. Internally there is a nucleus of gray matter, the corpus dentatum. Externally we find two layers, an outer with a few round cells and fibres, and an inner with nucleated cells very closely connected. The cerebellum cannot be stimulated mechanically. The puncture of the cerebellum does not cause pain but may result in flexing of the head. If the middle crus is divided the animal will rotate around the long axis toward the divided side. Ferrier has stated that irritation of the cerebellum produces motion of the eyes. By experiments on a pigeon, dividing the cerebellum in parallel sections from the upper surface, there is found a progressive loss of locomotion. The first stage represents the weakness of motion; this is followed, when half of the cerebellum is removed, by staggering; finally, when it is all removed, it is unable to support itself. None of the senses seems to be destroyed. This indicates that the cerebellum has to do with the co-ordinating power of motion independent of the sensations; the function of the cerebellum therefore is the securing of proper co-ordination of movements By the influence of the cerebellum the various muscles of the body concerned in body movements are caused to act, each one at the proper time and to the proper extent. Peripheral impulses pass to the centers from the nerves of sense originating in the skin, muscles and viscera, from the nerves of hearing and from the optic nerve. It is supposed that all these impressions are collected together in the cerebellum, but how the impressions are co-ordinated is unknown.

THE CEREBRAL HEMISPHERES: The cerebrum consists of longitudinal and transverse fibres. The inferior portion of the crura cerebri consists of bundles of longitudinal fibers springing from the anterior pyramid of the medulla, these

fibres passing into the internal capsule, the fibres reaching the brain. Among the fibres localized are sensory fibres from the posterior areas, from the roots of the optic nerves and the olfactory lobes: the fibres of the pyramidal tracts passing through the internal capsule terminate in the parietal lobe and the middle lobe of the cortex. The gray matter of the hemispheres is connected with intelligence, hence mental disturbance is associated with a diseased condition of the gray matter. A sudden injury or compression of fluid effusion resulting from inflammation, produces unconsciousness. If the pressure is taken away consciousness may be restored. If there is disease, on the other hand, in the white matter, paralysis may result or convulsions without any loss of consciousness. Thus the gray matter on the surface of the cerebrum is associated with consciousness and the mental phenomena. This fact is the foundation fact in psychopathy, forming the basis of remedial treatment of insanity. If the gray matter of the hemisphere in a pigeon is gradually sliced off the animal becomes more and more stupefied and looses all consciousness, perception and volition being lost. Perfectly normal movements may be produced by stimulating the external surface. Such movements are purely reflex, are not accompanied by consciousness of the external stimuli and are not the result of voluntary effort. If the animal is fed it will live for months in this condition of stupor. A frog from which the cerebral lobes have been removed may be made to go through all the normal movements by a suitable external stimulation. Such movements in the frog never take place spontaneously, but only when stimulation is applied to the surface, indicating that the actions are purely reflex. It will therefore appear that it is only through the cerebral hemispheres that the will is able to work and that the processes set up in the cells of the hemispheres as a result of the influence of the will causes impulses to travel along a nerve to the lower centers from which efferent impulses eminate to the muscles. It may be taken as proved the nervous processes and activities connected with volition, sensation and the other mental phenomena take place in and only in the nerve cells of the gray matter of the hemispheres. In early times it was supposed that all parts of the cerebral cortex had the same function. Broca discovered that the effection of speech was associated with a lesion of the third frontal convolution. In such a case the person may know the object but cannot name it. This was the earliest location of function in the cerebral hemispheres, later it was found by Schiff and others that electric stimulation of the surface did not affect muscle movements. Ferrier then took up the subject using the faradic current. Experiments made by him over the surface of the hemispheres led him to the conclusion that each hemisphere may be divided into three zones: (1) A posterior connected with sensory impulses; (2) a middle in which are found a number of motor areas, the stimulation of which, at least, in the case of the monkey produces particular movements. These area as are grouped around the fissure of Rolando; (3) an anterior containing inhibitory areas. Much discussion has arisen as to these areas. It has been found that by the removal of the gray matter there follows

a weakening of the movements controlled by the area; after a short time these signs of weakening disappear. From this it is concluded that if one motor area is destroyed some other part may take up the function. Goltz experiments on the removal of the gray matter by washing so as to prevent hemorrhage. He found that there is a power of recovery from the removal of a certain area the paralysis being due to the injury exciting the inhibition of other centers. It is suggested that definite movements do not depend solely upon a definite area but that they may depend upon two or more areas so that if one area is destroyed the function may be performed by another. Different parts of the hemisphere seem then to have different functions. In proof of this we find that tumors pressing on a particular part of the hemisphere are associated with paralysis of special muscles, the successful removal of these tumors being followed by the disappearance of the paralysis. What we referred to before as aphasia due to the lesion or imperfect nutrition of the inferior frontal convolution of the left side is another proof of localization of function. Localization has taken place of the following:

1. For the head and neck in the posterior portion of the first frontal convolution.

2. For the facial muscles in the posterior part of the second.

3. For the articulatory movements in the upper portion of the third left frontal.

4. For the arm at the middle of the descending frontal.

5. For the leg the upper portion of the ascending convolutions close to the fissure of Rolando.

6. For the eyes the posterior parts of the first and second frontal.

7. For the body muscles the convolutions of the corpus callosum.

According to Harsley and Schafer the areas are not definitely separated from each other as they overlap each other, for example, the face area is said to take in the ascending parietal and frontal convolutions to the Sylvian fissure. This area represents the eye, nose, mouth in its upper part and the jaws, tongue, lips and under part of the head together with the vocal cords in the lower part. In the same way the sensory areas have been localized. The angular gyrus represents the sight center. If the two gyri are destroyed total blindness follows without motor paralysis. The auditory area was localized in the superior-tempora-sphenoidal convolution just below the fissure of Sylvius, the taste and smell area at the extremity of the temporo-sphenoidal lobe and the touch area in the gryus uncinatus and hippocampus major. Horsley and Schafer locate the sensibility area in the gyrus fornicatus. It may be generally accepted that the posterior part of the brain is concerned principally in receiving sensory impulses, whereas the motor areas concerned in the sending out of impulses is associated with the middle and lateral regions whereas the frontal or anterior lobes are concerned in psycological actions including volution, cognition and intelligence. Thus the gray matter may be topographically divided into three great areas: (1) the anterior or frontal concerned in psychic phenomena; (2) the motor area representing the middle region, and (3) the posterior region representing sensory impressions. This

division may be accepted as a working theory in order to aid in the localization of pathological condition of the psychic and also the physiological.

THE NERVOUS SYSTEM AS A WHOLE: The mass of the nervous system changes with age and certain other conditions. Along with this general change are found other changes in the relations of the different parts to each other, these variations producing the characteristics that are found at different stages of life. The specialization of function is so entirely dependent upon form especially in connection with the nutriment of the entire nervous system that changes resolve a complete change activity. In the central nervous system the cells represent the smaller proportion by weight, the neura and the substance of the system representing about 90 per cent. In addition to the cells and the nerves we find the vessels for the conveyance of blood and lymph and also the supporting tissues, these representing a mass usually estimated about equal to the cell bodies. The brain is sometimes weighed without the blood when it is cut up into sections, and sometimes with the blood. Sometimes the pia is also eliminated before weighing the brain, the pia averaging in weight from 40 to 60 grams. There is also a proportion of water varying from 70 per cent. in the white matter to 80 per cent. in the gray matter. The specific gravity is estimated at 1036 there being a variation in the different layers increasing from the outer surface inwards. The variations in weight depend somewhat therefore upon the changes in the different elements constituting the tissue. Among individuals we find variations which chiefly depend upon the changes in the nerve cells, the larger the mass as a whole representing larger cells and consequently a larger substance within the cells subject to chemical changes such as produce the changes in energy. There may be also a variation in the nerve fibers representing an enlargement or diminution of the pathway along which impulses may travel. There are said to be five standards of the brain, the smallest estimated from 300 to 1000 grams in males and from 280 to 900 in females, the small in males 1001-1250 in females 901-1150, medium in males 1251-1450 in females 1151-1350; large in males 1450-1700, in females 1351 to 1500 and the largest in males 1700-1925 and in females 1501-1745.

The ordinary adult brain is represented by the medium. In the lower races of people we find the smaller encephalon. Among the same races, however, there are differences depending upon age, sex, stature and size. From 20 to 40 years of age represents the average adult size of the brain, the male encephalon being always heavier than the female varying from 125 to 185 grams at different ages and in different body sizes. Those of larger stature generally have a larger brain, the weight increasing to about 40 years of age and thereafter gradually diminishing, the changes being most marked after 70 years. The same changes are not found in connection with body weight at least so constantly, perhaps chiefly because of the large proportion found in large bodies. The change in weight found in old age is probably due to the general decrease in nervous activity resulting in more or less atrophy of the nervous system as a whole.

In the changes found in those of larger stature the difference is probably due to the increase in the size of the cells and the nerve elements. The same thing is possibly true of the difference in the case of sex, the individual cell elements being larger in the male. This difference does not depend upon functional activity as we find the same differences between the brains in the two sexes in the lower races in which the intelligence and brain activity is at its lowest and also in the case of the lower mammals. This seems to indicate that the difference is due to the size of the nerve elements rather than to an increase in the number of those elements. In the comparison between the brains of those occupying the lower strata of society and those of eminence in the social and intellectual world it is found that on an average the latter have heavier brains, and yet among those who have held eminent places in the social and intellectual scale there are found great variations in the weight of the brain, indicating that a large brain weight does not necessarily imply a high degree of mental capacity. The observations made by Manouvrier in connection with the brains of criminals and insane persons indicate that there are usually among those classes brains of lesser size. There are, however, differences among the insane depending upon the character of the insanity.

In regard to the spinal cord very few observations have been made, the average weight in cases subjected to experiment giving the variation from 24 to 34 grams. In the central nervous system we find normally a symmetry in the two halves of the system. This, however, is subject to exception that from a physiological standpoint the central nervous system is one sided. In nearly all the cases reported there is a variation in weight between the right and left hemispheres. The same absence of symmetry is said to exist in other parts of the brain for example, in the cerebellum in which it is said that the molecular layer is thicker on the left than on the right side. These variations are explained by some in connection with the blood supply. The left carotid furnishes a more perfect supply of blood to the left hemisphere than the right carotid to the right hemisphere, and this would furnish a stronger nutritive influence in connection with the left hemisphere. This may account for the greater development on the left side, but as yet nothing definite has been formulated. The brain and spinal cord pass through many cases from the period of birth up to maturity. In the cases reported by Vierardt the weight of the brain after birth is in the male 381 grams and in the female 384, after the first year in all the reported cases, 839 being examined by him, the female is less than the male. From these records we find that at birth the brain weight is about one-fourth of its weight at maturity. It increases in weight very rapidly during the first year, the increase being gradual until about the eighth year after which it is slow. In some cases about the 15th year in males and the 14th in females there is an abnormal development of the brain which if too rigorous produces death or at least is found associated with death at that age. These reported cases of Vierordt are all hospital cases and it must be remembered that these represent individuals not of the normal upper or middle class but rather those of the lower

classes. Hence it has been inferred that conditions and circumstances have much to do with brain growth and also with senile brain atrophy. The point, however, noted is the general development up to a certain point after which maturity continues for a lengthened period after which decay sets in. According to the older physiologists the male child at birth is heavier than the female. This, however, is contradicted by later researches that indicate the female larger or more nearly equal, the difference in weight arising later in connection with brain development. The development of the brain differs from that of the body in that the former is more rapid, this development being usually almost completed before the 9th year. At this period the body has not attained more than one-third of the adult body size. This indicates that the brain and body development do not go side by side for at birth the brain represents a little more than one-eighth of the body weight whereas in adult life the brain represents less than 1-50 of the body weight. This change is due largely to the large muscle growth in the adult life. From the standpoint of embryology it is pointed out that the increase in the number of nerve cells ceases after the 3rd month of intra uternie life. The development of the nervous system after this takes place by the enlargement of the embryonic cells. Side by side with cell devolopment we find also the development of the nerve fibres these nerve fibers being either medullated or non-edullated. The non-edullated fibers are found in connection with the sympathetic system where the function is less differentiated and also in the central system. It is suggested that medullation represents a perfected condition and non-medullated in imperfect condition the latter representing a condition which is found associated with part of the nervous system throughout life. At birth the central nervous system posesses only imperfect medullation, the development representing largely the completion of the medullary portion. The medullated portion and the axes cylinder form about equal parts of the fibers. The fibers form as we said above 90 per cent. of the encephalon and about one half of this would represent medullation. It is estimated that in the entire central nervous system there are three billions of cells. In the central system about one-fourth represents the sustentacular tissue and blood vessels and the remainder nerve tissue proper. All of these cells in embryonic form it is calculated can be accommodated in an area of 3 C. C. which which would represent the size of the nervous system in the foetus at the end of the 3rd month. In the case of the mature system it is estimated that there is an increase of 450 fold representing a cell which is within the normal limits of cells in adult life. Thus we find the development of the nervous system is due to a gradual enlargement of the cell elements found in the early embryonic stage, this enlargement taking place in the cell proper, and in the formation of the neura together with the increase representing medullation in all of these changes following the development we have already considered.

In the central nervous system a development becomes more complete the system becomes capable of greater activity as the impulses are increased and thus

the power of the nervous system becomes enlarged representing new functional development. The system in other words becomes more fully organized. In embryonic conditions the cells are isolated from one another. Out of this primitive location the neuroblasts migrate coming more closely together and forming as we have seen cell combinations. In the organization of the nervous system changes take place in the neura and the dendra. These are extended by development, the neura developing outwards towards the dendra, the dendra also growing so that there is constant approximation of the two towards each other. In the central system as well as in the sympathetic system medullation is not necessary to functactivity; all the fibres becoming medullated originate from non-medullated fibres so that medullation represents organization. In the afferent cells we find an increase in the neura and their branches presenting a larger surface for stimulation. In the central cells we find the increase of the neura and the dendra increasing the facility of receiving and sending out impulses. The efferent cells develop largely by the increase in the dendra. Thus, the chief development of organization depends upon the central cells which branch out in all possible ways. Imperfect development may be localized in any one or all of these different ways generally however deficient development takes place in only one way. Although the deficiency of one usually involves a weakening of the rest. In this development the blood supply is an important consideration. The most delicate blood vessel connections are found in the closely packed groups of cells. In this close relation of the blood vessels to the cell bodies in the gray matter we find the basis of the change taking place in connection with these cells. The brain is a very delicate organ and it is necessary that it receives an abundant supply of blood and that it should not be subjected to shocks from the pulsating vessels or pressure from over filled vessels. These are secured (1) by the tortuous course of the arteries which carry the blood to the brain; (2) by the fact that the arteries are finely divided before entering the brain substance, the division taking place in the pia mater; (3) by the cerebro-spinal fluid and the continuity of the cranial cavity and the spinal canal. Hence, if for any cause an unusual amount of blood enters the cranial vessels a corresponding amount of cerebro-spinal fluid pours down into the spinal canal and so the pressure on the brain substance is prevented. There is no reflex variation in the blood vessels as there are no vaso-motor nerves in connection with the vessels of the brain or cord. Thus the blood varies very little as we find it circulating in the central nervous system. If the arterial pressure rises the blood flows more rapidly through the brain but there is a corresponding increase in the venous blood flow. The amount of blood normally in the brain and spinal cord is small, not more than 1-100 part of the entire blood of the body. During mental activity there is an increased blood flow to the brain; when fatigue or exhaustion follow there is a diminished blood supply to the brain. Not only does the brain require sufficient quantity of blood but especially blood of a sufficient quality. It is said that the thyroid has an important influence upon the blood supplied to the nervous system as

their removal results in nervous weakening due to malnutrition. The use of thyrodin is said to have beneficial results in cretinous conditions.

In sleep we have the lessening of activity arising from diminished impulses passing through the central nervous system. This diminuation may result from a voluntary reduction of the afferent impulses. Following this we find the nervous system ceasing gradually to give a response representing either a condition of fatigue or the exercise of volition. During childhood the sensory impulses are not distributed over as large a sensory area and the impulses stored in the nerve cells are few as compared with those found in the adult condition. The same thing would be true of old age although in childhood there is a capacity of development which we do not find in old age the nerve activity having become exhausted to a large degree. In the same way we find the supply of blood ranging with age so that the amount of energy capable of being yeilded varies with childhood, maturity and old age. Exercise induces a fatigued condition giving rise to afferent impressions that when conveyed to the centers produce the sensations of fatigue. In connection with the body activity both of muscle and nerve there are certain substances which when conveyed to the blood act as an inducent of sleep. Mosso has pointed out that if the blood of a dog fatigued by over-exertion is transferred into another dog that is not at all fatigued the latter dog will give signs of fatigue. It is inferred that there are certain metabolic products in the transferred blood that have wrought the change. The same thing is indicated by the difference in the sensations of fatigue depending upon the form of fatigue and its inducing cause. Therefore the preceding condition of sleep may be summarized (1) suspension of stimulation; (2) cessation of response in the case of the nerve centers; (3) a product of some kind in the blood, and (4) a decreased supply of blood to the brain. These conditions can be produced artificially by removal of the stimulation and by the use of certain anaesthetics. The loss of blood or the retarding of the circulation of the blood to the brain by pressure upon the carotids induce unconsciousness analogous to sleep. These artificial conditions, however, differ from normal sleep in the effect upon the central nervous system; in the former case there is more or less of a disturbance caused by the artificial means used to induce it while in the latter case normal cells acts as a restorative of energy upon the central nervous system. Much discussion has arisen as to what takes place in sleep. The central nervous system never losses its power of responsiveness, if such were the case it would be impossible to arouse anyone out of sleep. The person asleep is never removed from the influence of external stimulation. The plethymograph has been used to demonstrate this. The arm was placed in the instrument and the person allowed to go to sleep. It was found that after falling asleep stimulation insufficient to arouse from sleep produced variations in the volume of the arm due to the removal of blood from the arm. This must have increased the circulation of blood in the brain without affecting the sleep in any way. This shows that during sleep the nerv-

ous system is capable of respone without any consciousness of a reaction. Measurements have been made of the amount of stimulation necessary to awaken out of sleep. A ball was allowed to fall upon a plate with a view of producing a sound sufficient to affect the auditory impulses and thus by experiments made it seems that the first period of sleep is deep whereas the after periods are light gradually becoming lighter until the period of wakening. This, however, gives no indication of the action of the central nervous system or of the changes taking place in connection with sleep as a restorative of exhausted energy. The loss of sleep has an important effect upon the system producing irritation and resulting in death more rapidly than the deprivation of food. Experiments have been made on young dogs according to which the loss of sleep for four days results in a fall of body heat and the loss of reflex action, accompanied by changes in the blood, hemorrhages in the brain and a shrivelled condition of the spinal cord followed on the fifth or sixth day by death.

During the decline of life we find certain changes involving alterations in the cells and throughout the entire nervous system. During the normal conditions of life there are certain metabolic changes taking place in connection with the cells, these changes depending somewhat upon age. In youth the anabolic processes prevail, whereas during old age the katobilc processes prevail. As we have seen the brain decreases in size. There is a shrinking of the whole nervous system, involving both the cells and nerve fibers. It is claimed by some that the fibers decrease in number, especially the motor fibers. In the same of paralysis agitans the nerve cells become shriveled, marked generally by degeneracy extending to the fibers. Accompanying these changes we find an increase of the sustentacular tissues and an induration of the blood vessels accompanied by thickening of the vessel walls. Changes of this kind are more frequently found in the lumbar area of the spinal cord. This condition it is said represents an excessive degeneration such as is found in a lesser degree in the spinal cord of all aged persons. In regard to the brain the patholiogical examination has disclosed the fact that the chief changes in the brains of old people are found in the cerebellum where the cells are shriveled and in some cases completely degenerated. Thus degeneration, destruction and shrinking represent the condition of the brain and the spinal cord during old age, the dissolution taking place in such a way as to render the nervous system less active, less responsive and subject to eradic activity. The physiologists have largely limited their investigations to the separate parts of the central nervous system without attempting to formulate any plan of systematic action on the part of the system as a whole. This has produced in physiology a tendency to overestimate the importance of specialization of function, over-looking the fact that there is a solidity and unity of action on the part of the entire system. It is probable that easy active operation of the nervous system effects the whole system, in this way there must be constant activity on the part of the nerve cells accompanied by continual impulses entering and leaving these cells.

This forms the basis of "the continuity of conscious experience." Behind consciousness, at least, from a morpholiogical standpoint there lies the anatomical structure of the nervous system but as yet no one has been able to solve the problem of their relations. The region of consciousness has been gradually moving upwards with the development of physiological theories until, as one physiologist has said, it has had to take refuge in the only remaining region after the sensory and motor areas have been localized, namely, in the anterior portion of the gray matter of the cortex. Ancient philosophers did not limit the mind to the brain. With the dawn of modern psychology the center of conscious, mental, emotional and volitional phenomena was associated with the medulla, in more recent times to be localized in the frontal area of the cortex, largely because this is the only portion of the brain left for its localization. Even if we could understand all the changes taking place in this region we should be unable to bridge the chasm between the purely subjective and the objective, much less would we be able to resolve mental phenomena into their preceeding causes. Philosophy has divided mainly into two schools, the one paterializing the mental phenomena by ascribing them solely to physiological and physical causes and the other idealizing by calling them figurative names which in reality give no explanation of the phenomena themselves, By the combination of both of these ideas we have a fundamental, physical and physiological basis for the ideal interpretation of these phenomena. If we enter into the realm of the transcedental and premise the existence behind all these phenomena whether physical or mental of metaphysical essence, then an explanation becomes more clear, because these phenomena of mind and body become simply manifestations of this inner, deeper and truer existence. The difficulty in this case is that such an essence which metaphysics would identify with soul cannot be proved in a possible way by science. At best it is simply a metaphysical conception. Without attempting to solve this question there is an important physiological question, if physiology has any ground for localizing consciousness and the entire psychic phenomena in the frontal area of the brain. If we can interpret aright the facts of comparative physiology then this theory is not founded upon fact. Physiologists localize in the brain sensation that is here terminated, all those impulses which result in consciousness. Yet the other portions of the nervous system which convey the impulses to this sensorium may have as much to do with consciousness as does the sensorium itself. In the lower animals whose brain development is very simple, possessing none of the characteristic corticle convolutions associated with mental phenomena in man we find consciousnes. This view is based upon the perfect unity of the body and especially of the nervous system. It gets over the difficulty which modern physiology emphasizes of perfect localization of the different functions. In the earliest conditions associated with cell development we find the single subject to stimulation undergoing certain molecular changes, these changes sending out impulses to other cells and also along nerve paths to the surface of the body. In the first cell which is more or less differentiated in

function by reason of the capacity of receiving and transmitting impulses becomes more fully specialized by continued stimulation so that its changes are accommodated to this special kind of stimulation and respond to such external stimuli as it has become accustomed to have we have the first beginnings of consciousness and also of memory. Consciousness even here is not the product of the changes that take place in the cells, because even a knowledge of all the internal changes would not involve consciousness, as the consciousness would only arise in connection with some external manifestation. Some have explained this by presuming that there is associated with matter consciousness, but this cannot be, because we find no connecting link between physical matter and psychic consciousness. Therefore, we find two seeming opposites neither of which is the cause or is caused by the other. This connection has been completed by some who have identified energy of some kind with the causation of consciousness. Energy, however, is a physical attribute in virtue of which certain matter or matters posess the power of acting, this action depending upon the active changes taking place in the constituting elements. If these changes which we suppose to take place in the cells upon the basis of molecular activity form the basis of consciousness, then consciousness must be a material and not a psychic quality, because the result cannot contain more than is found in the cause. The simple substante changes or matter movements cannot therefore explain consciousness. Consciousness is therefore inexplicable unless we hypothecate the psychic as we do the physiological, each one in its own sphere forming the basis of its own characteristic activity. If we consider the nervous system as consisting of a complexity of nervous mechanism, each mechanism in its simple form constituting an activity in which there is consciousness, then the entire nervous system would represent a complex series of conscious states from the psychic standpoint. Consciousness must exist then not only in the case of the entire brain but in all the cells that constitute the complex brain. If stimulation is applied to a sensory part of the body an impression is carried into the central nervous system, a reflex movement of some kind resulting. There is here a reflex action which has no volition at least from the brain center and yet there is a consciousness of the changes taking place in connection with the reception and distribution of the impulses. The center of reflex action outside of the brain has a close connection with the cells in the gray matter of the brain so that every sensory area of the body has a connection with some portion of the brain. Impressions may pass outward reflexly from these cerebral centers to other centers resulting in involuntary movements, but impulses may also pass from these sensory centers in the cortex to the centers of volitional impulses resulting in voluntary movements. Every voluntary action is however essentially a reflex action depending upon afferent stimulation either at the time when the action is called forth or at some prior period.

The impressions made upon the cells or combinations of cells are retained, thus constituting memory so that when the impulses are aroused volition has a

basis upon which to act. If we add to this the fact that by means of vision when an image is formed upon the retina the optic nerve transmits it to the corpora quadrigemina where co-ordination takes place from whence it is carried to the optic region in the cortex. This image when impressed upon the cell constitutes a memory picture which, under the influence of impulses, may be awakened in consciousness so as to call forth activity. These sensory impressions may, however, not only be aroused to consciousness in the cerebrum, but also in the cerebellum, where co-ordination takes place. It is probable that sensory regions are found both in the cerebrum and cerebellum. If this is so then the convolutions of the cerebrum and the cerebellum represent, the latter the seat of regular, rhythmic movements that are not dependant upon volition, whereas the former represents the voluntary element in all movements. When different sensations are produced.the action of an object or objects as stimuli upon different parts of the sensory surface, molecular changes are set up in the different cortical regions, these regions being connected together by the fibers of association so that when consciousness receives these different impressions they are combined to form a single idea. Instead of being combined, however, on the mental picture, these combined impulses may give rise to muscle movements, the movements depending largely upon the stimulating causes. When the stimuli are strong the impulses pass to the nerve cells in the brain where, on account of their strength, they make a vivid impression upon the cells so that after the stimulation has passed away the impression continues, being subject to recall upon a slight stimulation either external or internal. Here we have the physiological basis of the association of ideas which occupies such a prominent place in psychology and also the basis of memory and recollection. By the constant repetition of these processes the impressions become so closely associated with the cell bodies that they form an inherent part of the cell itself and constitute a part of the cell life so that by heredity these are transmitted from generation to generation forming the physiological basis of mental intuitions. These intuitions represent modifications of the brain under the influence of mental development, each brain representing its own stage of progress in evolution. Where we have a great number and variety of impressions we find the great variation in the cell changes and a corresponding variety in the mental phenomena When these impressions are so fixed in the brain that stimulus from another part of the brain can call forth a response, we have a fully developed metal condition. In this way the pictures of scenes seen by the sense of vision or objects brought into contact with the sense of touch may be stored up within the brain cells to be awakened at the call of some mental stimulus. Some physiologists say that they may be aroused spontaneously. This, however, is probably incorrect as what seems to be spontaneous awakenings are dependant upon weak stimulations, often indirect. The sight of an object may arouse impressions formerly associated with such an object with one analogous to it, the simple call being sufficient to arouse the dormant impression. In this way we find that phenomena which at first seem

purely voluntary and arbitrary become purely reflex or at least cease to be associated with conscious volition. In the case of the child persistency of effort enables it voluntarily to walk. After childhood these movements may be quite unconsciously performed. In the same way mental phenomena may become purely unconscious, so much so that certain actions are often spoken of as being done instinctively.

It is generally conceded that there may be unconscious mental activity, the result of this mental action later lessening consciousness. Mental development implies the receptive condition of the nerve cells and also the active operation of these cells in the changes involved in molecular development. These are regulated somewhat by the capacity of selection in the case of different impressions by the concentration upon particular impressions to the exclusion of others, by the activity of the cells in connection with the particular impressions and the power of associating these impressions. Each of these elements has a physiological basis in the central nervous system, and they may become more stable by discipline, the brain development depending largely upon proper exercise. This implies that individuals differ from each other in the original constitution of their nervous system, this forming the basis of different degrees of intelligence and psychic initiatives as we find these among different individuals. These, however, are based primarily upon hereditary acquisitions handed down along with the system itself from ancestors. Thus to each one is given by birth not only a body but also a mind, the basis of mental character and development. When man starts out from this initial point in his mental history his development is determined largely by environing conditions and educative processes. The power of volition may also be increased by exercise so that the inhibitory influence also depends largely upon the same educative influences. Not only is there a basis for the normal physiology of the mind in the physiological condition of the brain and nervous system. The same basis is found from the pathological conditions of the mind. Insanity represents mental abberation of some kind. Therefore an insane condition is always associated with certain abnormal organic brain conditions or with certain functional derangements. Fluid effusions, blood clots, softenings and atrophy of the brain cells or fibers, have an effect upon the mental condition resulting in weakness of mental comprehension, incapacity to respond to external stimulation, erratic conditions of melancholy, delirium and delusion. It is often difficult to point out the relation between a nervous lesion and the mental weakness, or rather to trace the unbalancing of the mind to the physiological abnormality which produces it, but this does not prevent us from making the statement which psychology fully bears out, that abnormal brain conditions and functional derangements form the basis of all insane conditions. Any disturbance affecting the brain must also affect the mind and every change that affects the nerve substance of the cell affects at the same time the mind. Every impediment to functional activity also impedes mental activity. Ferrier states that brain disorders are of two kinds—psychological and physiological, and the

basis of both of these disorders is mental abberation of some kind. Any degree of lesion to the nervous system may result in mental disorder. From a pathological standpoint mental diseases may be classified under three heads:

1. Those depending upon minature or imperfect brain conditions.

2. Those arising from actual diseased conditions of the brain.

3. Those resulting from injury to the brain in a normal condition.

1. As we have seen the normal brain is of an average size among Europeans varying from 44–55 ozs. Brains below 30 ozs. are usually associated with imbecility, accompanying this mental weakness there is usually also body weakness. Maudsley says that the superiority of the human subject mentally over the animals is connected essentially with man's capacity of a greater variety of muscular activity. To such an extent does he think this is true that if man with a normal brain were deprived of all the movements of face, hands and limbs, he would fall into idiocy. If the Muscular system is undeveloped many of the channels of nervous development are cut off. This simply brings out the close relation between mind and body both in strength and weakness. Over against the fact that a small brain is usually associated with imbecility: insanity is often associated with a large brain abnormally developed, numerous cases of insane persons being recorded where the brain weight was 60 or 61 ozs. Weight, however, is not a sure test. There is more stress to be laid upon the character of the cells and the nerve fibres. Out of a large number of cases examined, only a few fell under the head of small brains. This is explained by some as due to the fact that idiocy is produced, not by imperfect development, but by disease, three-fifths of the idiots whose brains have been examined having over-developed brains. Dr. Severini records the case of a little girl whose brain weighed 9 ozs., the girl being reported as possessing all the senses, with intelligence but little below the average, afterwards leading an erratic life. Through lack of education and discipline her mind was not developed, so much so that it became impossible to educate her although she could distinguish between right and wrong., In the pathological examination of this brain, the lack of development was chiefly in the cerebral hemispheres, although they were perfectly symmetrical. All the cerebral lobes were small, the parietal and occipital being very small, the frontal and temporal being more perfectly developed. The corpus callosum was very thin and short. The frontal region of the hemispheres was most fully developed corresponding with the intellectual condition. By microscopic examination it was found that the nerve cells were scarce on account of the abundance of connective tissue, the nerve cells being triangular instead of pyramidal. These were abnormal conditions and indicate the possibility of great brain variation with possible intelligence. If in this case the mind had been trained the likelihood is that wonderful mental ability would have been noticed as a result. It seems evident that much can be accomplished by proper training in the case of those having undeveloped brains. Among those who have been engaged in the training of this class it has been the plan to fol-

low the principle of the connection of mind and body directing all efforts to the co-ordinate discipline of both mind and body. We realize in this field of work that physical and mental training go hand in hand, although the two forms of training are entirely different, the physical training aiming to develop muscle and nerve and the mental aiming to develop self respect and self thought. Seguin says it is impossible to correct a disordered mind so long as it is impeded by disordered body functions. This is meant as a criticism of those who direct attention to one to the exclusion of the other. To feed, clothe and guard an imbecile is simply to reduce it to vegetable life, to confine the same individual in a prison among imbeciles is to perpetuate its imbecility. As feebleness of mind and feebleness of body usually go hand in hand the education and treatment of mind and body should go hand in hand, the improvement in one aiding in the development of the other. Here Osteopathy can efficiently help the enfeebled body and assist pyschic therapeutics to cure the mind.

2. As every body organ is libable to disease so is the brain, and this depends upon its physilogical relation to the other body- organs. So-called mental disease have been associated with loss of reason to such an extent that we have almost lost sight of the fact that a brain disease is just like a lung or liver disease, the result being that the merest approach to brain disorder is called an incurable disease because supposed to be localized in the mind. It is true that the mind is more susceptible of disease than other organs, chiefly because of its relation to voluntary activity. It is true also that unnatural causes seem more often to induce brain disorder than the usual body diseases, but brain diseases may be due to natural causes like all other diseases. Brain disorder affects mental experience. The incipient conditions of brain disorder are said to be disturbance of either personal experience or emotional conditions. But there are also the physical signs of normal body diseases, the only difference in brain disorders is that the disturbance affects both the mental and the physical life. These disordered brain conditions may result from a great many causes, connected with the blood supply, whether excessive or insufficient, compression upon the brain substance, inflammation of the tissues, and hereditary weakness, exposing the brain to abnormal influences, for example, wasting conditions of different parts of the brain, the lack of development on one side of the brain, a wasting away of the white substance of the brain or the adherence of the membrane to the gray matter of the brain—these are typical examples of post mortem examinations of disordered brains, diseases being found in those parts of the brain which normally represent the seat of the power of control. The disordered condition of the brain involve the element of mind, the mind being unbalanced as well as the body deranged. In treating such cases attempts have been made to nourish the washing tissue, to sooth the disordered condition and to restore functional activity. Along with this there is mental activity developed so as to train the mind to action along with the recurring functional activity of the brain.

There are thus two problems for solution—the problem of the brain condition and the mental condition. In a great number of cases idiocy results from inherited physical weakness, this infirmity involving the mental disorder of lack of development. Sometimes a strong physical constitution accompanied by heredity and a weak mind, but in this case what is required is strong training to develop the mind. To this we may add that by heredity children do not inherit the ignorance of their ancestors or their intellectual attainments, but an organism either highly developed or infirm and a corresponding development of brain. Insanity, as distinguished from idiocy, is also in a large number of cases caused by physical causes. Maudsley has pointed out that hereditary weakness and excesses result in insanity. Turning to the physiological cause we find that degeneration of the brain representing physical conditions resulting in insanity, indicating that there is a diseased condition physically which must be treated like every other disease. In addition to these physical signs there are mental phenomena. Post mortem examinations have often disclosed brain diseases where no mental disorder has been noticeable. Ferrier states that this may go to such an extent that an entire hemisphere may lose its organization without any effect upon the mental condition. The hemisphere divisions seem to make it possible for a great deal of brain disorder to exist without any serious impairment of the mental activity. If a single hemisphere is sufficient to carry on the physiological life it may be presumed to be sufficient to carry on the mental life. Brain lesion may be in the sensory or motory regions, and may thus only slightly affect the psychic centre of activity. In the case of delusions there seems to be, in most cases, the existence of judgment and the power of reasoning, at least in regard to the subject of the delusions. Thus the intellectual condition does not seem to be impaired, the delusion itself depending upon a condition of the brain. Even when the brain degenerates after the wasting has advanced, the mental activity seems continued with considerable force. Although this interest may be aroused for a time, there is a point reached in the wasting condition of the brain where mental activity ceases. Mental derangement depending upon brain disorder may be produced by very strong emotion. In most cases there is a hereditary predisposition representing a weak bodily or mental condition. The producing cause, however, may be the absence of self-control when free play is given to some of the passions. In the case of predisposition the body is usually weak and the nervous system excitable, and any unusual emotional condition may give rise to mental derangement if it comes with suddenness. The reason of this is that when the person is nervously high strung self-control is impossible. Where passion comes into play the body may be strong but the suddenness of a disaster or other inducing cause may lead to the loss of self-government, particularly if the mind is not well prepared for such a change. In this case the body health usually gives way under the mental strain, whereas in the other case the body health is weak and assists in the

weakening of the mind. Dr. Browne says that brain pressure may have two kinds of results in a sudden emotion which comes without exception, or a suddenly aroused intellectual effort, giving rise to acute mental derangement in the form of mania, whereas in emotion that comes gradually, inducing excitement, slowly impairs the mental faculties, inducing a demented condition. In dealing with the insane it is not sufficient to treat the body system with a view to restore body health. There must be also a mind treatment, whether we speak of it as a moral or mental therapeutic. It is true that in ordinary treatment more attention has been paid to medical and dietary considerations. These, however, are not enough. There is care taken to promote cheerfulness of disposition, to provide varying occupations and recreations. In treating with the insane, restraint and coercion have been proved hopeless methods. Dr. Sankey says that in treating the essential part of a patient's disease who is affected mentally, care must be had to rest the brain, rest representing the principle of treating mental disorder. This seems to be opposed to the entire philosophy of mind which bases mental soundness on activity. Hence it would seem that in the dealing with the mind the activity of the mind must be secured on the basis of individual judgment, so as to secure the coutrol of the mental activity by the patient himself. Of course, rest from the old method of coercing an insane person into submission, rest as opposed to fear, represents a decided advance. But it is not sufficient to give rest. There must be an attempt to direct the mind to self-reflection, with a view to control the mental activity. So soon as this regulation is secured the mental balance is gained. "The aim of the newer method to cheer, to conciliate the patient, to produce good feelings towards his custodian, to raise, not to depress him, to fill his mind with pleasurable emotions." By leading the mind forward in confidence it is possible to inspire in the mind a self-controlling power. This can best be accomplished by kindness and kindred dispositions. When these dispositions find a response in the patient's mind there is induced the childlike disposition which prepares the patient for leaning on himself. Just as we teach a child to walk by allowing it to lean on some support, and then when the confidence has been inspired as to the ability to use the limbs the stay may be removed; so in the case of the weak mind, by inspiring confidence the way is opened to self-confidence and self-control. In accomplishing this, three forms of treatment are possible: (1) Association. Companionship is distinguished from the old method of this relation with companionable beings, forms the first step in the new treatment. (2) Occupation. It is this form of treatment that calls forth mental activity and establishes later self-control. Mental employment favors physical development. Dr. Maudsley says that the only scientific treatment of the insane is based upon freedom from restraint, this involving freedom from the causes which produce the disordered condition, and also liberation from self by engaging the attention upon something external to self, so as to compel the patient to free himself from his

own repression. This is best done (3) by interesting and varying recreations. Activity is the best cure for insanity, particularly if that new mental activity is directed outside of the old relations. In this way personal activity is necessary in order to secure control of the mind. There is one condition of insanity that deserves special notice, namely, the moral perversity that takes the place of departing sanity. This is particularly the case in persons whose lives have been most exemplary. To build up moral character is not the work of a day, but of a lifetime. By daily victories over self and successes in removal of dangers to the moral life an amount of decisiveness is attained which represents character. If at this point bodily weakness arises, or if a sudden change in the moral atmosphere appears, there is a sudden shock to the system, under whose influence all the good of former years gives place to evil, resulting in melancholy and forebodings. In all probability here we have a condition where such a sudden change takes place that the mental control is lost and the animal nature prevails. In such a case as this the treatment should be wholly mental and should be directed to the mental stimulation so as to arouse interest, the probability being that body stimulation would only increase malady.

(3) Where the brain is healthy and is overtaken by a sudden or violent injury we find a different mental state. Here the injury is presumed to be accidental. The brain, although protected by the skull, is often exposed to serious injuries. These have been lessened by skillful surgery, which can remove lesions and tumors and extirpate unhealthful tissue elements which are dangerous to mental soundness. Still there are possible lesions that often seriously affect the brain. In this case injuries induce conditions mentally which otherwise seem to be produced gradually by different causes. A healthy child fell some ten or twelve feet, the head striking a hard surface. Only a small scalp wound appeared on the right side. In a few minutes he was seized with an epileptic fit. These fits recurred for years at regular intervals, first of a few weeks and later of a few days. Preceeding the fit the head always turned slightly to the left side. This is followed by loss of consciousness and convulsions. After growing up, the mind exhibited considerable weakness, the memory being very weak. This implies that there is induced in some way mental inhibition. In the case of the brain Dr. Ferrier says "that sudden and extensive lacerations may be made in the præ-frontal region and that large portions of the brain substance may be lost without causing impairment either of sensation or of motion; and, indeed, without any evidence of disturbance of any kind, bodily or mental, especially it the lesion be unilateral." This has an important bearing on the functions of the frontal lobes, which have been associated with the intellectual elements of the mental life and especially the power of self-control. Cases have been sighted in which lesions in this region have interfered with the power of self-control without much interference with the intelligence. Dr. Bastian has stated that he believed the posterior lobes

were more connected with intelligence than the anterior, as there is more danger of mental impairment by injuries to these posterior lobes. It seems, however, that, so far as recent investigations have resulted in anything definite, the irritation is first noticed in the frontal region in cases of mental disorder. It must be remembered, however that following this initial stage, which seems to be located in the anterior portions, there are two succeeding stages during which the irritation sweeps over the entire region from the anterior to the posterior, and that finally there is a sudden shock in the posterior region. Some have concluded from this that the brain acts as a whole in mental phenomena, although the controlling and governing part is located in the anterior region. It has been demonstrated that a portion of the brain substance may be lost without any detriment to the mental acts, some say with positive advantage. This, however, is doubtful, as the brain is so fitted normally for the skull cavity that in normal cases there is a distinct relation between the skull cavity and the brain. It is true, however, that tumors formed in the brain involving pressure on the brain interfere with functional activity, and the same thing is true of fluid effusions in the brain. These, however, may be removed so as to remove the derangement and restore normal functional activity. In addition to this it is claimed that in some cases brain development takes place sometimes to such a degree as to cause a pressure on the gray matter upon the skull, producing compression of the brain. This would seem to indicate that while mental activity acts through the substance of the brain, mind is itself superior to brain and mental action to brain action. In other words, that mind is a metaphysical essence and that the brain is simply the physiological medium in which mental manifestation takes place.

The Peripheral Nervous System: In the peripheral system as distinguished from the central nervous system we find fibers originating from the central nervous which as distinguished from the central system are called peripheral. We have (1) spinal nerves; (2) cranial nerves and (3) sympathetic nerves.

(1) Spinal nerves. Originating from the spinal cord there are thirty-one pairs of nerves, each nerve having an anterior and posterior root. The posterior root is attached to the dorsal surface of the cord, is thicker than the anterior root, attached to the ventral root. The posterior has a ganglion, called the spinal ganglion, in which we find bipolar nerve cells. These two roots unite together to form a single trunk beyond the ganglion. The fibers of the anterior root are motor and of the posterior root sensory. Bell found that by stimulating the anterior roots in an animal, very soon after death, muscle contractions followed; while the stimulation of the posterior roots produced no effect. By the irritation of the posterior roots, if the irritation is strong, pain may be produced, the result following the irritation of the peripheral end of the anterior roots. This pain will continue if the main trunk is cut beyond the junction of the two roots, but it will cease if the posterior root is divided. This seems to indicate the presence of sensory fibers passing around from the

posterior to the anterior root, called loops, these loops being traced out by Wallerian degeneration. The afferent and efferent fibers run along the trunk of the spinal nerve, dividing at the junction, the afferent fibers passing into the posterior root and efferent fibers in the anterior root. If the anterior root is cut the muscles supplied with nervous connection cease to contract. If the peripheral end is stimulated the muscle will contract, if the central end is stimulated there are no sensory impulses. If the posterior root is divided the muscles supplied with nervous connection continue to contract, sensibility being lost where the nerve distribution takes place. If the central end is stimulated sensory impulses are felt, but if the peripheral end is stimulated no effects are noticable. In regard to the spinal ganglion there is no evidence that it can act independently as a reflex center, nor can it originate independent efferent impulses. It is intimately connected with the nutrition of the nerve fibers. If the posterior root is cut between the spinal cord and the ganglion the portion attached to the ganglion continues intact, degeneration taking place towards the spinal cord. If the anterior root is divided the spinal portion remains intact, while the peripheral portion degenerates towards the junction of the fibers with the trunk, the fibers degenerating in the trunk being efferent fibers. If the posterior root is cut between the ganglion and the junction with the anterior root, the part towards the ganglion remains intact and also the root from the ganglion to the cord, while nerve fibers in the trunk degenerate, these being afferent fibers. If the spinal ganglion is completely extirpated the entire posterior root degenerates and also the afferent fibers of the nerve trunk. The afferent fibers thus develop away from the spinal ganglion towards the periphery and centrally towards the spinal cord, whereas the efferent fibers grow out from the spinal cord towards the periphery, in each case indicating the course of nutrition from the nerve cell. In the anterior roots we find efferent fibers without any ganglia and splanchnic fibers and also delicate ganglionated fibers whose ganglia are found at a distance from the central nervous system.

(2) The cranial nerves. These pass through the foramina in the base of the cranium. Of the cranial nerves three are exclusively associated with the special senses of the optic, auditory and olfactory. Two are common nerves and also connected with sensation, the fifth and eighth, the former having a motor fiber of its own, the latter receiving motor fibers from the vagi roots and from the spinal accessory. All the rest are motor, the facial being associated with sensory fibers. Gaskell makes two divisions of the cranials: (1) four nerves with full segmented development, of which portions are lost because their function is lost; the third, fourth, sixth, and motor parts of fifth and seventh. (2) Five segmented nerves in which division has taken place to compensate for lost nerves; the eighth, tenth, eleventh and twelfth, and the sensory portion of the fifth. (a) The olfactory nerve, or nerve of smell. This consists of non-medullated nerve fibers, which come off from the olfactory bulb originating by three roots from the frontal

lobe, the anterior white commissure and the sphenoidal lobe. Branches are distributed to the upper two-thirds of the ethmoidal portion of the mucous membrane of the nasal fossae. If this nerve is cut the loss of the power of smell results, though irritating odors can still be appreciated, as these stimulate the nerves of ordinary sensation which pass to the nasal fossae. It is purelys ensory. (b) The optic nerve. It has three roots, the anterior arising from the posterior portion of the thalamus optici; the middle from the external corpus geniculatum and anterior the corpora quadrigemnia and the posterior from the internal corpus geniculatum and the posterior corpora quadrigemnia. These constitute the optic tract, the two optic tracts uniting in the formation of the commissure. It is purely sensory and is the nerve of sight. Division of it results in blindness. Stimulation causes light sensations. Normally the light must make impressions upon the nerve through the retina. (c) The oculo-motor nerve. It arises near the origin of the fourth, in the gray matter above the Sylvian aqueduct. Passing from the internal crural margin it terminates in two branches, the upper supplying the superior rectus and the levator palpebræ superioris and the lower rectus internus and rectus inferior and also the inferior oblique, the circular fibers of the iris and the ciliary muscle. From the lower branch a nerve passes to the ciliary ganglion. On the opposite side this nerve is connected with the posterior portion of the parietal lobe. It is purely motor, supplying all the muscles of the eyeball except the superior oblique, which is supplied by the fourth, and the rectus exturnus supplied by the sixth. Hence, when the third nerve is cut the eyeball is turned outwards and downwards, the upper eyelids drop, the pupil dilates and the power of accommodation is lost. If the two branches are solid the vision is adapted to both eyes. When the muscles are paralyzed, after division there is double vision due to the elevation of the image on the paralyzed side. (d) The fourth, or trochlearis nerve. This arises close to the root of the third. After crossing the nerve, fibers appear on the upper crura cerebelli. It is a motor nerve and supplies the superior oblique muscle of the eye, regulating eye rotation. When this nerve is paralyzed the head turns in a slanting position towards the paralyzed side. If the nerve is cut the eye turns upwards, instead of rotating downwards and outwards, and it also turns to the one side. (e) The fifth, or trifacial nerve. It arises by two roots, one root (sensory) originating in the gray matter of the medulla and a motor root arising from the nuclei of gray matter. These arise from the side of the pons, the motor being short and the sensory large, having on it the Gasserian ganglion. The sensory root divides into three, (1) the ophthalmic branch, which supplies sensory fibers to the eyeball, upper eyelid, nasal fossæ and forehead, the conjunctiva, nasal mucous membrane, the periosteum and frontal, orbital and nasal regions, etc. It also supplies the lachrymal mucous membrane, influencing the lachrymal secretion. It has also connection with the otic ganglion and the vaso-motor nerves to the iris and retina. (2) The superior maxilary branch supplies sensory fibers

to the lower eyelid, nasal fossæ, pharyngeal region, Eustachian tube, upper teeth, palate, chest, etc. It also supplies the nasal and palate glands and furnishes voso-motors from the sympathetics. (3) The inferior maxillary branch supplies sensory fibers to the lower teeth, mucous membrane of the mouth and tongue, the skin of the lower part of the face, chin, lips, gums, etc. With this third branch there joins the motor root, which supplies the muscles of mastication, the anterior belly of the digastric and the mylo-hyoid muscles. Thus the inferior maxillary is senso-motor. If the sensory root is cut sensation is lost in the external and mucous surfaces of the head, face, in the salival glands and also the lachrymal glands and the teeth, while the tongue loses both sensation and taste. Mastication becomes difficult on account of loss of sensibility. If the nerve is cut on one side the jaw is pulled to the one side that remains intact. We find among the ganglia (1) the ophthalmic. If destroyed the cornea becomes insensible and the pupil becomes dilated. The fifth supplies all the sensory fibers, the motor fibers coming from the third and the sympathetics. (2) The spheno-palatoid is found in connection with the superior maxillary branch. Removal does not affect smell or taste, and no change takes place in the trophic influence exerted upon the fibers. The facial, by the great superficial petrosal, supply the motor fibers, the fifth supplying the sensory fibers, together with sympathetics from the carotid plexus. (3) The otic ganglion is associated with the inferior maxillary. The motor fibers probably come from the facial through the small superficial petrosal and the sensory fibers from the glosso-pharyngeal, and the sympathetics from the plexus of the middle meningeal artery. It is through this ganglion that the secretory fibers pass to the parotid gland. (f) The abducens, or sixth nerve. It arises from the middle of the fourth ventricular floor, passing between the medulla and the pons. It supplies the external rectus muscle of the eyeball. If the nerve is cut the eye is dragged internally, resulting in a rotary movement of the eye. Six miscles supply the eyeball, the four recti muscles, the two oblique muscles. There are seven pairs of nerves engaged in the optic work. The obicualris palpebraum close the eyelids, the seventh supplying the nervous connection. Sometimes the origin of the facial is involved on the opposite side if this muscle is paralyzed. If the other muscles are paralyzed, the facial trunk is affected. When the eyelids are half closed the upper lids falling over the eye there is a paralysis of the levator palpebræ superioris affecting the third nerve. The muscles supplied by the third nerve produce rotation of the eyeball internally and also upwards. The superior oblique supplied by the fourth moves the eyeball down and out. In paralysis of the third, the eyeball be extended down and out with divergent strabismus. If the fourth is paralyzed, the ball is directed up and internally with convergent strabismus just the same as in paralysis of the sixth. Strabismus involves double sight and always has more or less movement of the head in the attempt to rectify the vision. This usually produces unsteadiness in locomotion. (g) The seventh nerve consists of two parts, the facial and the auditory. The portio mollis arises in the gray matter on the floor of the fourth ventricle and has connection with the cerrebellum, its function being auditory. The portio dura arises in the deep portion of the pons at the level of the sixth nucleus.

The portio dura arises in the deep portion of the pons at the level of the 6th nucleus. The nerve fibers run backward and inward to the floor of the 4th ventricle. bending outward to pass over the 6th nucleus bending forward to the lower margin of the pons. If the nerve is divided at its root the muscles of the face will be paralyzed, the features being drawn toward the solid side. The side paralyzed becomes more prominent, the eyes being wide open and bulging. On one side the lips are paralyzed although mastication is not suspended. There is an affection of the speech interfering with the pronounciation of certain letters and sounds, a lessening of salival secretion and a interference with deglutition, sometimes the hearing is also affected although sensibility is not lost. This is the special nerve of facial expression. It is connected by a fiber with the auditory nerve. After passing into the Fallopian acquaduct it enlarges into the ganglion geniculatum where connection is established with the otic and and spheno-palatine ganglia by the small and large superficial petrosals. At its origin is not sensitive, for example, in anastomosis with the vagus. (h) The glosso-pharyngeal. The 8th. pair of nerves consists of three seperate nerves,the glosso-pharngeal, the pneumogastric and the acessory.

1. The glosso-pharyageal is in the main a sensory nerve the sensory roots arising from the floor of the 4th ventricle. It has motor roots that arise in the gray matter of the medulla. It is distributed to the mucus membrane of the back part of the tongue, the pillars of the fauces the epiglottis and the tonsils and also to the tympanic membrane and the Eustachian tube. It. is also distributed to the mucous membrane of the pharynx.

2. The pneumogastric arises in the medulla, the deep origin being in the gray matter close to the floor of the 4th ventricle. Most of the fibers pass through one of the two ganglia, the upper and the lower, the lower fibers passing without entering either of the ganglia. Between the ganglia there is a junction of the vagus and the internal spinal accessory, forming the motor portion of the vagus. There is also a junction of the vagus with the sympathetics, the hypoglossal and the glosso-pharyngeal. The vagus is distributed to the larynx, oesophagus. stomach, intestine, lungs, heart, liver. The sensory fibers supply the mucus membrane of the larynx, the heart, the, the back of the tongue, the palate, oesophagus, stomach and duodenum. The muscles supplied by it are sensitive the mucous membrane of the bile ducts and the back part of the auditory canal. The motor fibers control the palati muscles, the pharyngeal constrictors and the oesophagus. The artytenoid and crico-thyroid muscles are supplied by the superior laryngeal, all the other laryngeal mucles being supplied by the inferior laryngeal. The vagus also furnishes the broncho-dilator and constrictor fibers. The vagus also has cordio-inhibitory fibers and the depressor fibers. It also furnishes nerve connection to the liver in connection with the formation and secretion of glycogen.

3. The spinal accessory arises from nuclei in the medulla and from roots of the spinal cord in the anterial horn. It is a motor nerve and sends branches which supply the sterno-mastoid and trapezium muscles. In vocal sounds it acts in connection with the glottis from its internal branch. It sends out

branches that join the vagus supplying the laryngeal muscles.

4. The hypo-glossal originates in the lower portion of the floor of the 4th ventrical supplying with motor fibers the extrinsic and intrinsic muscles of the tongue. One branch of it the decendens noni forms with a branch from the upper cervical plexus a loop from which twigs pass to supply the infra-hyoid muscles. If it is divided the muscles of the tongue become paralyzed, preventing articulation and rendering deglutition difficult.

5. The Sympathetic System.—We find two kinds of fibers (a) medullated fibers like those in the central nervous system and (b) non-medullated consisting of gray fibers. These arise from the sympathetic ganglia. The medullated fibers arise from the central nervous system. If the medullated fibers pass through the ganglia they lose the medullation. The sympathetic fiber passes through a series of ganglia connecting the ganglia, these ganglia and fibers extend from the cranial base to the coccyx in symmetrical arrangement on both sides of the spinal cord. Thus the sympathetic system on each side consists of a main trunk with 24 ganglia and minute fibers the sympathetic trunk being connected with the central nervous system through the spinal nerves the connecting fibers being medullated and non-medullated. The majority of the sympathetic fibers are non-medullated. In the lower regions the two main trunks on opposite sides are connected about the middle line. In the upper regions both trunks unite with the 8th and 9th cranials passing to the cranium along with the internal carotid forming connections with all the cranial nerves except the 1st, 2nd and the auditory branch of the 7th. This connection is established directly with the 4th, 6th and 9th with the 3rd and 5th through the opthalmic ganglion, with the 4th and the facial branch of the 7th through the spheno-palatine otic, and submaxillary ganglia, also with the facial branch of the 1st through the geniculate ganglion. As the sympathetic fibers distribute to the viscera numerous plexuses are formed in which ganglia are found. If the sympathetic is divided in the neck the blood vessels are dilated on the same side increasing the blood supply and the temperature as well as the lachrymal and sweat secretions. If the cephalic end of the cut nerve is stimulated these effects disappear indicating that the sympathetic system furnishes the nerve connection for the walls of the blood vessel so as to maintain them in their normal condition of tonic constriction. These nerves are the vaso-motor fibers of the vessels. The cervical part of the sympathetic supplies the vaso-motor fibers to the head. These arise in the cervical region of the spinal cord coming out by the anterior roots of the lower cervical and upper thoracic nerves. The radiating fibers of the iris arise in the same place as the division of the sympathetic in the neck produce contraction of the pupil of the eye. The thoracic and upper limb vaso-motors arise from the inferior cervical and superior thoracic ganglia and also from the spinal cord. The lower limb vaso-motors arise from the cord, passing through the sciatic and crural fibers. The pelvic vaso-motors arise from the sympathetic ganglia in the abdomen. The vaso-motors from the abdominal viscera are found chiefly in the splanchnics, some fibers being found

in connection with the vagus. The splanchnic nerves are three, the greater, the smaller, and the smallest, originating in the human subject out of the thoracic ganglia of the sympathetic, the greater from the 5th to the 9th, the smaller from the 10th and the 11th, and the smallest from the 12th. The greater and smaller furnish nerve connection with the stomach, spleen, liver, pancreas and intestines. The smaller and smallest enter into the plexus that passes to the kidneys. If these are cut the vessels in the abdominal region becomes engorged with blood. If the peripheral end is stimulated contraction takes the place of dilatation. Thus the splanchnics furnish the vaso-motor fibres to the viscera. There is a relation between the central nervous system and the sympathetic system. If the spinal cord is divided there is a rise of temperature in the limbs. If the spinal cord is hemisected in the dorsal region there is a rise in the temperature in the lower extremity of the opposite side. This, of course, means dilatation of the blood vessels. If, after the section or hemisection, stimulation is applied to the peripheral end of the cord the dilatation gives place to contraction. From this it would seem that part of the vaso-motor influence comes from the spinal cord. Some physiologists declare that there are vaso-motor centers all over the cord, although the chief center is found in the medulla.

The Special Senses: The senses represent the external organ upon which an impression is produced. This impression when conveyed to the sensorium becomes the basis of a psychic perception. In all the senses there are three factors: (1) external stimulation in connection with some special organ that has connection with the nerve of special sense; (2) this impression must be transmitted along a nerve as an impulse; and (3) the impulse is received in a center or centers resulting in the consciousness of an impression. This implies the existence of sense organs, nerve paths of sensory impulses and a center. The impulse is passed from the organ to the center along the nerves of special sensation these nerves being specialized in function in connection with the action of the mind. This does not imply that each nerve fiber is different in structure but that the action of the excitant in connection with the center produce the special result. There is also a difference based upon the terminal organ, the terminal organ being so differentiated as to be capable of receiving only certain kinds of impressions so that each terminal organ is specially adayted to receive special stimuli. The sensory impression does not pass directly to the psychic centers. The impression is received in the localized reception center, this center having the power of transmitting or not these impressions to the center of perception. In connection with sight, for example we find the corpora quadrigemnia lying between the psychic centers and the optic region. In these optic regions impressions are received and when co-ordinated in the corpora quadrigemnia may be transmitted to the higher centers. These corpora quadrigemnia are supposed to have the power of storing up impressions so that impressions may be sent up to the higher centers without any external stimulation. There is time necessary for the transmission of such impressions after their reception. The excitation stimulates the

cutaneous structures. The impulse travels along the sensory nerves, is communicated to the brain and there distributed resulting in sensation followed by perception. After this volition is called into play with the result that an impulse starting in the brain passes along motor fibers to the muscles of movement or locomotion. The time occupied in this transmission included both the physical and the psychic processes. When there is stimulation of the sense organs this stimulation is produced by some form of movement, light being the vibration of ether, sound the vibration of the air and touch represents the changes of pressure due to varying oscillations. Thus the action of the normal stimulation depends upon the character of the wave movement, its length, its amplitude and its form. Weber has formulated a law bearing upon the intensity of the stimulus, if the strength of the stimulus increases in geometrical progression the strength of the sensation increases in arithmetical progression. This means that the intensity of a sensation depends on two things. (1) the intensity of the stimulation and (2) the degrees of irritability in the terminal organ effected. The stimulus may be the smallest or the greatest and a mean representing the medium or a constant ratio between the intensity of the stimuli and the intensity of the sensation. Different sense impressions vary and the sensations produced in connection with them also vary in quality, this difference depending largely on the variations in the vibrations of the air, for example, the lowest musical note is produced by 15 vibrations per second, while the sensation of the color red in connection with the spectrum represents 450 billions per second. These sensory impressions on reaching the brain become sensation; and if the mind refers this sensation to something producing it as a cause it becomes an idea. The connecting link between the sensation and the idea is called a perception. In the senses there are two divisions (1) those resulting from delicate movements or vibrations, taste, smell and vision; and (2) those resulting from changes in the pressure upon the organ of sense, hearing and touch.

1. Sense of Taste. Taste is associated with the tongue and with the upper portion of the anterior surface of the soft palate and the anterior pillar of the fauces. we find both medullated and non-medullated fibres in the terminals of the glosso-pharyngeal. The medullated fibers freely multiply their branches in the connective tissue and form taste bulbs, while the non-medullated forms mesh works which represent the taste buds, which are minute branches in the epithelium. Ovoid bodies, the one end extends to the upper surface the other end decends till it rests upon the tunica, the superficial end opening into a minute canal on the surface. These taste bulbs are found in great number and represent the organs of taste. This is proven by the fact that when a substance is brought in contact with such taste buds there is taste. If the glosso-pharyngeal is divided these taste buds will degenerate. Insalivation is necessary in order that it may have taste and thus excite sensation. Hence substances must be soluble otherwise they do not stimulate taste It the surface brought into contact with the substance is large then the sensation of taste is increased, the degree of taste depending upon the degree of which the solid

substance is concentrated in the soluble form. The dilution of substance with water seems to diminish the sensation of taste, although in some cases, as in case of quinine the dilution requires to be very great. The power of producing the sensation of taste seems to vary with different substances, the substance of a sweet or acid or bitter character being more difficult to bring into the taste sensation than saline substances. The temperature most favorable to the sense of taste is that ranging from 10° to 30° C., either above or below this temperature the action being lessened. Sometimes taste and smell are confused although they are quite distinct. Taste is capable of wonderful cultivation, as is found in the art of testing in which every minute differences may be at once and accurately discerned. Taste may be interrupted by diseased condition of the tongue. Artificial sensations of taste may be produced by each substance in the blood, as morphia or the bile in jaundiced conditions, these producing a sour and unpleasant sensation. On the other hand those subject to diabetes feel a constant sensation of sweetness to such an extent in some cases that it seems almost impossible to satisfy the taste. In some cases of insanity there are such tastes often developed, these tastes arise in connection with the taste centres in the brain. Astringent substances are preceived only by the four parts of the tongue and bitter only by the back part, while sweet and saline substances. though tasted by the whole dorsum of the tongue, are best appreciated by the fore part.

2. Sense of Smell.—Smell is located in the mucous lining of the nose, nervous connection being established with the olfactory bulbs. The mucous lining is not all connected with smell but is limited to the anterior portion of the meatus, the medius meatus and the septum corresponding with these. The rest of the membrane is associated with the respiratory system. The olfactory nerve is distributed in the tunica propria, the greater branches being sheaths, the fibres being distributed into minute filaments ending in the epithelium, connection being established in some way with the olfactory cells. Medullated fibres of the trigeminal are found in connection with the mucous lining of the nasal cavity. To produce the sensation of smell the substances must be in the air or in the form of odors and gases. The substances must be very finely divided as we find in the case of closing up the nostril with cotton smells are still discernible, although very minute organisms are excluded from the atmosphere admitted. Perfume seems to fill the air and excite the sensation of smell without any appreciable loss of scent. A few grains of musk will perfume a room for years and yet not lose in volume. There are certain gasses that have no odor, as hydrogen, oxygen, nitrogen, water gas, marsh gas and ammonia. Some of these gases have an irritating effect but have no smell. The gases that have a smell are chlorine, iodine, bromine, arsenic, antimony and sulphur vapors, each of these having its characteristic perfume. The theory has been put forward that smell is due to vibrations of a kindred nature, as those giving rise to light. This theory is defended on the ground that to produce smell there must be weight exceeding that of hydrogen. On this basis Ramsey says that odorous substances must 15

times the weight of hydrogen. On the basis of this theory it is claimed that the kind of odor depends upon the kind of vibration among the substances. The sensation of smell may certainly be aroused by vibration but the vibration may be of such a nature as not to produce a smell. There is a limit both as to the minimum and the maximum of vibrations in the production of smell. It is claimed that the particles of odoriferous substance vibrate on the olfactory membrane producing stimulation sufficient to cause sensation. This theory has not yet been proved but there is no doubt that when the odors of flowers are carried on the breezes particularly in the early morning or in the evening the air is laden with the perfume. In the case of heavy substances that produce odors the substances maintain their weight in the air and are very persistent. It is for this reason that the air laden with animal odors continue to produce smell sensations so long. The air laden with the odor must be brought into contact with membrance, hence the first thing necessary to the sense of smell is that the person must breathe. By breathing the air is brought into contact with the membrane. In order that the contact may produce the sensation of smell the membranes must be moist. The greatest sensation occurs at the beginning of the sense of smell, although the intensity depends upon two other factors, (1) the extent of the membrane affected and (2) the manner in which the odor is concentrated so as to affect the membrane.

The sense of smell like the other senses is capable of cultivation to a considerable degree. Where the other senses are deficient or absent smell may become so sensative as to become the vesicle of considerable knowledge.

The Sense of Vision.—The sense of vision is usually caused by the action of the light upon the retina. Any stimulation of the optic nerve however will produce a sensation of light. But light itself has no power of directly stimulating the optic nerve. It can only do so when it acts on the nerve through the retinal rods and cones. In front of the retina are a number of curved surfaces and various media by which the rays of light from any luminous point as they enter the eye ball are refracted or bent so as to be brought to a focus on the retina. Hence when an object is looked at there is formed a picture of it. The retinal image is always as regards the object looked at reverted. When properly focused it is well defined and its size depends on the visual angle. The refractory apparatus consists of the anterior surfaces of the cornea, the anterior and posterior surfaces of the crystalline lens, the substance of the lens and the aqueous and vitreous humors. The rods and cones are the portions of the retina sensative to light. There has not yet been established a direct nerve fibre connection with these although such a connection is probable. There is undoubtedly a union between the ganglion cells and the axis cylinder of the nerve fibres. The cells, however, are not nearly so numerous as the nerve fibres, hence the fibers must have a connection in other ways. The optic nerve within the cavity of the eye ball is bound up in sheaths, these sheaths containing the brain membranes. The fibres when found in bundles are medullated without, however, the sheath of Schwann. A sensation of light is de-

pendent upon sensation of either the optic nerve or the retina. The usual stimulus is light, but artificial stimuli, such as mechanical pressure, division of the nerve or electric shocks, may act as stimuli. Light from a physical standpoint is a vibration which is found in the ether that fills all space. These vibrations affect the retina, producing molecular changes which stimulate the fibres of the optic nerve. This impulse is transmitted to the brain resulting in light sensation. Physically light is a kind of movement, physiologically light is a stimulus that produces sensations, its action upon the organic elements of the special senses resulting in the special form of conscious sensations called light sensation. These vibratory movements as they are found external to the organism have been studied carefully in physical science, but physiology has been unable as yet to study the result of these movements in the complex body organism because consciousness only takes account of the result. The sensations of light depend upon the phenomena associated with light. When there is a disturbance of the surrounding by a luminous body an impression is made upon the retina resulting in a light sensation. This vibration is originated from the luminous body and travels almost instantaneously in all directions. If these vibrations are intercepted by a dark sheet in which there is a small opening, the vibrations of light will penetrate this opening, moving in a direct line so that the light moves in a straight line. Hence the movement of light is said to be rectilinear. If the light thus moving rests upon a smooth surface either a part or the whole of a beam changes its movement by reflection, the light reflected moving in a direct line perpendicular to the surface of reflection. the two rays of light, the one received and the one reflected, forming equal angles with the surface of reflection, If the media on the two sides on which the ray of light falls are transparent then part of the light is refracted, that is, it bends at the surface where it passes into the second medium, so that the light refracted lies in the same plane with that of the original light ray. The media of refraction may be glass, water, air or diamond. The course of the ray is a matter of mechanical calculation depending upon the knowledge of the principal points in connection with the generated ray of light. In the eye we find four refracting surfaces, the anterior and posterior surfaces of the cornea, and the anterior and posterior surfaces of the lens. As the cornea surfaces are almost paralel and as the refraction index of the cornea does not differ much from the index of refracting of the aqueous humor, the posterior surface may be omitted. In the case of the lens we find varying degrees of density throughout the crystalline, the density being increased toward the center. From this standpoint the eye is an optical instrument possessing the power of refraction through a transparent medium. The eye is thus an optical apparatus consisting of a refracting surface and a lens, the lens in this case being complex in character. When an object is placed before the eye an inverted image falls upon the retina. the refraction through the transparent media producing the different points of the image. While the eye is symmetrical as an optical instrument. it is defective. but the defects as a rule are

so slight and we become so accustomed to them that they do not cause any errors in visual judgements.

These defects are (1) due to aberration of refrangibility. This is due to the fact that the different rays of which white light is composed are unequally refrangible, hence in a ray of white light falling upon a conversion lens the violent rays are more strongly bent than the red rays and are therefore brought to a focus in front of the red rays resulting in the reproduction and fixing of the color. The term chromatic aberration is used to designate the same defect of vision. The existence on the eyeball of different refractive media of various densities tends to correct this defect. This means that if there is perfect accommodation for the eye for one color there is not perfect accommodation for the other colors. Normally in vision this effect of the different refrangibility of different colors does not effect vision, but it can be discovered easily if we look at a violet light in which are rays from the two extremes of the spectrum, the eye will see either a small blue point with a red surrounding or a red point with a blue surrounding, according as the eye is accommodated to to the red or blue rays of light. (2) Due to the reflective curvatures of the reflective surfaces of which we find two varieties.

(a) Spherical aberration. The aberration of sphericity is due to the fact that when rays of light fall on a convex lens those which fall on the outer or marginal part are more strongly bent than those which fall near the central part of the lens and as a consequence the rays on the marginal end will be brought to a focus in front of the rays near the centre. Hence in the eye ball the whole of the rays of light are brought to a focus exactly on the retina and so the image formed is more or less blurred, there is formed a circle of effusion increasing according to the extent to which the pupil is opened. If the pupil is quite open then the vision is more marred. There are in the eye ball certain arrangements, the object of which is to diminish this defect as far as possible: (I) the iris acting as a diaphragm cuts off the outer rays so preventing them from entering the marginal part of the lens by which they would be stronger refracted: (II) the anterior surface of the cornea is not perfectly spherical but the marginal portion is less convex than the central portion; (III) the anterior and posterior surfaces of the lens to some extent correct each other; (IV) the lens substance is more dense towards the centre, hence the circumferential portion being less dense is less refractive than the central part.

(b) Astigmatism.—By this is meant that a vertical and a horizontal line at the same distance from the eye cannot be seen plainly at the same time, it is due in the main to the fact the vertical curvature of the cornea is more convex than the horizontal; hence the rays that fall on the former are more strongly refractive and are brought to a focus in front of those that fall on the latter. There is not symmetry in the refracting surfaces, so that in place of the circles of diffusion we find figures or lines irregularly shaped. Astigmatism is usually divided into a regular and an irregular; the former representing the difference in curvature between the horizontal median line and the vertical median line, so that

the eye lacks the power of accommodating the two rays representing the vertical and horizontal. In this case both lines cannot be seen at the same time, generally the vertical median line is more curved than the horizontal. This defect may be correeted by the use of plain cylindrical glasses, as they increase the refraction of the rays in the horizontal media until there is a common focus for the horizontal and the vertical. In irregular astigmatism there is an irregular variation in the curvature in different median lines, this being due chiefly to the variation in the crystalline lense. In order to have clear vision the image must fall on the retina. If the eye is adjusted so as to see a certain object, the rays coming from a point farther away will be focused before reaching the retina a divergance from the focus of the retina being represented by a circle of diffusion, the same thing will be true of a point nearer the eye. By sighting these different points the circles of diffusion are formed and when the centers of these circles co-incide the sighting is accomplished. There is a line of sighting in these cases which is formed by the axis of the conicle sides of the rays from the two points. the marginal border of the iris forming the boundry line.

In the case of a luminous object before the eye the rays from the surface cross in the eye, forming an inverted image in the retina. The angle at which the rays from the marginal surface cross is called the visual angle, its size depending upon the size of the object as well as the intervening space between the object and the eye. Objects of the same size at different distances may have the same visual angle. In this way the size of the retinal image may be calculated, if we know of the object and its size. If small opaque substances are found in the transparent media there may be a shadow cast upon the retina, giving rise to images which may be supposed real, as existing in the outer world, while their existence is really in connection with the media of sight. These are called eutopic objects as distinguished from the external objects of vision. These eutopic objects may be of two kinds:

1. Intra-retinal, arising from opacity in the retinal layer anterior to Jacob's membrane. This may be produced artificially by casting a strong ray of light on the border of the sclerotic by which a figure of the retinal vessels will be produced, it may also be produced by looking at a vivid light through a small hole before which quick back and forth movements take place. In this case also the retinal vessels will be produced. By looking at a very bright light through a tube moving the head backwards and forwards the circulation of the blood in the eye, and even the blood corpuscles, will be produced in the form of a picture.

2. The object may be extra-retinal, due to some opacity in some of the refractive structures in front of the retina. These may be seen in various forms and shapes according to the substance or structure of the substance. These facts seem to indicate that the most sensory portion of the retina is the deepest of the layers. the layer of the rods and cones. We have seen that in order to see objects clearly the light reflected from them must be accurately focused upon the retina. but as at different times we see clearly objects at different distances, there must be in the eyeball some arrangement by

which focusing power can be altered, for the nearer an object is to the eyeball the more divergance of the rays from it which enter the eye. Therefore the greater the amount of refracting or bending will be required to bring them to a focus on the retina. Hence, to see near objects clearly we require greater refracting power to see distant objects clearly. If a camera is placed in front of an object it requires to be focused to get a distinct image on the plate. The focus of objects at different distances is obtained by the alteration of the position of the plate relative to the refractory lens, moving the plate forward when focusing distance and backward when focusing nearer objects. In the eye there is a natural mechanism for such an accommodation. This is accomplished by changing the refractory power of the refractory apparatus, increasing it when looking at nearer and diminishing it when looking at distant objects. There is one compound lens composed of different media of refraction, the focal length being definite. There may be a difference between the focal length and the antero-posterior axis of the eyeball. In the case of the normal emmetropic eye the refracting apparatus is such that rays of light originating beyond a definite point. 65 meters distant, and which are practically parallel to each other. are brought to a focus on the retina. If this axis of the eye is longer or shorter of the focal measure of the length of refractive media then it is out of measure for ametropic. From luminous points within a distance of 65 meters, more or less divergent rays of light fall upon the eyeball and therefore refracting power is required to bring these to a focus on the retina, that is accommodation is necessary. In accommodation the chief change is an increase in the convexity of the anterior surface. There is also a contraction of the pupil and an increase of the intra-ocular pressure in the posterior part of the eye. The increase of the convexity of the anterior surface of the lens appears to be due to the contraction of the cillary muscles which by its contraction pulls off the cillary processes from the suspensory ligament. When the latter is no longer pressed upon the capsule of the lens will be dimished. Hence the lens by its elasticity bulges forward or becomes convex anteriorly. The nearer an object is to the eyeball the greater the amount of refracting power that is necessary, that is a greater increase in the convexity of the lens is needed to bring it to a focus on the retina. When an object is placed nearer the eye than 12 centimeters it cannot be accommodated, for it is too near. The rays of light passing from it are too divergent to be sufficiently bent to bring them to a focus on the retina. Hence a normal emmetropic eye accommodation takes place between 12 centimeters and 65 meters, the points represented by the distances called punctum proximum and punctus remotum. From the emmetropic there are two divergences in the ametropic: (1) The myopic, or short sighted eye. The ordinary myopic eye of short sighted people has either in the curvature of the refractory surfaces too much convexity or the antero-postero axis of the eye is too long. Hence the rays of light from a distance are formed in front of the retina and concave glasses are needed to correct the defect; (2) The hypermetropic, or long sighted eye. In long sighted people we find either the curvatures of the surface are not suf-

ficiently convex or the antero-postero axis too short. Hence when rays of light from a distance are brought to a focus behind the retina accommodation is always necessary, convex glasses are necessary to correct the vision. In the case of presbyoptic eye of old people we find an eye in which the power of accommodation has become defective in consequence of the weakening of the cillary muscles, flattened and diminished elasticity of the lens. The person as a consequence cannot distinctly see an object unless held at some distance from the eye, weak convex glasses should be used to correct the defect. If the two eyes have equal refractive power they are said to be isometropic, if different anisometropic. If a convex lens converging parallel rays of light is put in front of a hypermetropic eye the focal point can be moved so as to center it on the retina. Similarly if the concave lens is placed before a myoptic eye the focal point will be moved back until it rests on the retina. In both of these cases clear vision will be restored. The number of lens required to accomplish this gives the bases for the rectification of sight. The opticians use a metric scale in which the unit is a lens of one meter focal distance to which the name dioptic is given. The next, number two, would be 1·2 the focal length and a lens of double the power of number one, and so on. In the normal, the lens is flattened anteriorly by the pressure of the anterior layer of the capsule. When accommodation takes place the cilliary muscle fibers pull forward the cilliary processes and the retina, the lens is then bulged forward and becomes thicker. During the resting condition of the eye the zonule of Zinn s subject to some tention. But in the action of the cilliary muscle there is a pulling towards the edge of the cornea the ora serrata being drawn towards the corneal margin, lessening the radial tension of the zonule. In the cilliary ganglion, these arising from the third nerve, so that if the third nerve is paralyzed the accommodation is lost.

The light entering the eye is partly absorbed by the pigment and partly reflected. The rays reflected return through the pupil uniting with the entering rays to form a picture. The eye pupil is black when looked at because none of the reflected rays are receive into the observing eye. If the retina is strongly illumined with light and you place a lense in front of it so as to focus the rays in the observing eye a picture of the retina may be observed. It is on this principle that Helmholtz's ophtalmoscope is constructed. When there is a peficiency of pigment in the eye it appears luminous producing reflection of the rays of a red or pink color. If there is set in front of the eye a dark sheet with a hole of equal size with the pupil of the eye the hole will be dark instead of light. Where this pigment is absent as in the case of some animals it is called tapetum the eye being in this case more sensitive to the rays of light. This tapetum is always higher than the entrance point of the optic nerve. In some animals it is of a bluish color due to irridescence produced by the interruption of the light waves. When an image is reflected on the retinal surface it is reflected upon the arc of a spherical surface. The eye in this respect is more nearly perfect than a camera in which the surface is flat. This forms the reason why in a camera pic-

ture of a large object the outside of the picture is less fully developed than the central part, because the outside surfaces are not in focus. Sometimes these external parts become distorted. In the case of the eye, as the rays fall upon the concave surface all the rays of light are focused so that the image becomes quite distinct.

Functions of the Iris:

1. The iris acts as a diaphragm which prevents the rays of light from falling on the outer or marginal part of the lens by which the rays would be so strongly refracted that they would be brought to a focus in front of the retina. The iris thus prevents the formation of a blured image.

2. By the contraction and relaxation of its muscular fibres it determines the size of the pupil and so regulates the amount of light entering the eye. The radiating fibres contract, producing a dilation of the pupil, whereas another system of radiating fibres on contraction produce a lessening of the pupil. The contraction of the pupil is due to the contraction of the circular muscular fibers of the iris, these being supplied by the 3d cranial nerve. The dilation of the pupil is due to the contraction of the radiating muscular fibres, these being supplied with the sympathetic nerve fibres which can be traced to the sympathetic system in the lower cervical and upper dorsal regions.

3. By the contraction of the circular muscle there is an accommodation for near objects as it cuts off the more divergent rays from the aperture of the pupil. The diameter variations in the pupil depend upon the intensity of the light falling on the retina. If the light is strong the pupil contracts; if the light is less intense the pupil dilates. If the light is strong in one eye it will produce contraction of the pupils of both eyes. These indications point to reflex action as the cause of the phenomena of sight, the optic nerve being the afferent pathway to the center in the brain. By the stimulation of the optic nerve the pupil contracts. It is said that the center is in the corpora quadrigemina because if these bodies are destroyed the pupil of the eye looses it mobility, the dilator fibers of the sympathetic arising from the lower portion of the cervical region and the upper part of the dorsal region. Aside from nervous connection the iris seems to have the power of responding directly to the stimulation of rays of light. In the case of a dead animal the pupil of the eye will contract if the light falls upon it for a long time. If, however, the opposite eye is covered no response to the light stimulation will be apparent. The pupil of the eye contracts under the influence of light. This is a reflex action:

1. The afferent nerve is the optic and the center is in the corpora quadrigemina in the floor of aqueduct of Sylvius, the efferent nerve being the third cranial. Both pupils contract even though strong light acts upon the one retina.

2. The pupil contracts in accommodation for near objects.

3. When the eyeball is turned inwards.

4. Under the influence of morphine, physostigmin.

5. In deep lumber.

The pupil of the eye dilates:

1. Under dimished intensity of the light.

2. When looking at distant objects and (3) under the influence of certain drugs, such as atrophine, cocaine, etc. In the case of the iris its main function is to control the light falling upon the eye so as to make the image upon the retina quite distinct. This function it performs in two ways:

1. By lessening the rays of light reflected from objects close at hand by taking away the divergent rays and permitting the parallel rays only to be focused on the retina; and (2) by preventing the divergent rays from being focused in the front of the retina. In both of these ways the light entering the eye is regulated so as to permit only those rays to enter the eye that would be of value to the retinal image. All the portions on the front of the retina are functionally arranged for the assistance of the eye in focusing an image. Light is the normal stimulus of the retina. Stimulation may take place mechanically or electrically in the case of the optic nerve not directly but by acting on the nerve fibers through the rods and cones, especially the latter. Hence light passing through the various refractive media has to travel through the thickness of the retina to reach and affect the rods and cones situated on the posterior aspect of the retina. The changes that are thus produced have to travel forward through the optic nerve fibers that lie on the anterior aspect of the retina. What the exact changes are that light produces in the retinal structure is uncertain. Several changes, however, have been observed, but how these lead to the stimulation of the optic nerve cannot at present be explained. When light falls on the retina there is a change in the electric current, this must be due to changes of a chemical or thermal character. If an animal after being killed out of the light and the retina is subjected to exposure of yellow rays of light, there will be found a purple color in connection with it, these being destroyed if the retina is exposed to the ordinary light, the purple becoming decomposed by the ordinary rays of light. The same purple color is found in the eye of the fœtus before birth, the purple being found in the rods, not in the cones. The light seems to affect the purple of the eye, the result produced being some chemical change producing stimulation of the optic nerve. When the purple is used up new matter of the same kind is formed from the coloring matter of the epithelium, the epithelium secreting the coloring matter from the blood that circulates close to it. The retina then is a physiological sensitive plate. The coloring matter being destroyed and restored by chemical changes, the action of these chemical changes resulting also in a variation of an electric kind. This purple coloring matter is not necessary for vision as the cones have no purple. There is in all probability, however, a colorless matter in connection with the cones which produces the necessary chemical changes. Thus when the eyeball has been kept some time in the dark the hexagonal pigmented epithelial cells situated in contact with the rods and cones have their pigment mainly gathered in the dark into the body of each cell and from each cell are short fillimentous processes which project a short distance between the rods and cones. Under the influence of light these processes become loaded with pigment and project between the rods and

cones a much greater distance. The retina examined a short time after death is of a faint pink color, but if the animal is kept in the dark and then killed the retina, except at the yellow spot, is found to be of a purplish red color. This is due to the presence of the coloring matter to which the name Rhodopsin is given. Rhodopsin is bleached by the white light. Hence in order to see it the retina must be examined by the sodium light. It is restored again in the dark, and if the retina is brought into contact with the hexagonal cells. Hence it is supposed that the Rhodopsin is formed in the outer part of the rods by the action of these cells. An electric current can be obtained from it, the current increasing with the light that falls on the retina. When the eye rests in the dark the coloring matter collects near the external portion of the rods near the junction of the internal and external segments. When exposed to the white light diffusion takes place of the coloring matter over the rod inward. The white light in producing this diffnsion elongates the rods. If the eye ball is pressed luminous impaessions may be produced. These impressions take the form of a luminous point surrounded by colored rings. These may be small or large, depending upon the rays of ligh falling upon the retina. If a current is passed along the optic nerve a little violet scintellation may be noticed surrounded by a dark yellow ring. If the edges of the retina are excited a violet spot may be noticed, if the current is passed from the optic nerve to the retina. Even when the eye is in a dark medium there is not absolute darkness, there being a slight luminous characteristic of the eye in the darkness, this being called the specific light of the retina. It appears from this that even in the darkness there is an activity of the molecules which produces the luminous sensation. The retina is not excitable to an equal degree in all its parts. At the point of entrance of the optic nerve there is no light sensability, this point being called the blind spot. By shutting the left eye and fixing the right eye upon a cross which is about an inch to the left of a round dark spot on a white surface and moving the surface toward and away from the eye, there will be found a position where the round spot entirely disappears the image resting upon the point of entrance of the optic nerve. At this point there is no sensibility of color. The most sensative part of the retina is the yellow spot at the center of the retina. It is especially used in direct sight. If the eye is fixed on a word in a certain line the rest of the line is indistinct. This is particularly true of the fossa fovea centralis where there are only the retinal cones representing a small area of about .2 m. m. Acute vision becomes gradually less acute on passing away from the yellow spot. The retina is most sensative after it has been resting, for example in the morning. It remains excited for a short time after a stimulus has has ceased to act on it. Thus a colored spot on a rapidly revolving disappears as a continuous band because the excitement of the first stimulii of the spot has not ceased before the spot has come round again. To excite to retina, if the stimulus is weak it must continue for a definite time, if strong it may be much shorter. An electric spark lasts only for about .000001 of a second, yet the spark is

sufficiently strong and extended to make a light impression. When there is rotation of an object or a color so as to produce a fusion of the successive impressions we have the persistency of retinal impressions. Normally an impression continues on the retina about 1-50 of a second. This persistency of excitement after the stimuli has ceased to act explains the postive after image, while the negative after image where light parts of the image correspond to dark parts of the objects seen and vice versa, as due to the fatigue of the retina. An after image is the picture of an object that can be seen after looking at the object for a time and then closing the eyes or looking at a dark surface. In order to excite the retina there must be a definite intensity of the light, this intensity of light stimulation depending not only on the luminous body but also upon the excitability of the retina. Hence after rest or after being in the dark there is an increase in the retinal excitability.

Light and Color:—Light is due to the oscillations of the ether. This is a a hypothetical substance supposed to fill all space and to occupy the space between all material substances. The color or tone of light depends upon and varies with the length of the ether waves. Color is a sensation aroused by the action of rays of light of a certain length upon the retina, that is it depends upon the rays that fall upon the retina during a definite period of time. With a certain number of rays we get a sensation of red and with double the number of rays the sensation would be violet. The brilliancy or intensity of light varies with the amplitude of the waves. If a beam of light is made to travel through a glass prism the light is not only refracted but it is broken up into several primitive colors from red at one end to violet at the other end. These collected on a screen are seen forming the spectrum. Thus white light is of a compound nature, the waves of red light are of such a length that 451 billions of them reach a given point in one second of time, while the waves that produce a violet are much shorter, 764 billions reaching a given point in one second of time. The waves of intermediate lengths form the other colors of the spectrum. Color is thus a sensation due to a particular kind of stimuli. If the waves are longer than the red waves they do not stimulate the retina but they are heat rays. Similiarly waves that are shorter than the violet rays do not excite the retina, they are chemical rays. By examining the spectrum we get a series of colors the one merging into the other, red, orange, yellow, green, blue, indigo and violet. These are the primitive colors. If two or more of these primitive rays act on the same part of the retina we have the mixed color sensations. There are two kinds of these mixed colors (1) those existing in the spectrum and (2) those that do not correspond with the spectrum colors. Two colors which when mixed together give the sensation of white are said to be complimentary to each other, for example, red and greenish blue. violet and greenish yellow, orange and cyanic blue. If white light rests upon a surface all the rays may be absorbed except the red. If the red rays are reflected then the color sensation is red. If the blue rays are reflected then the color sensation is blue. If we look through colored glass, all the rays are

absorbed except the glass color and thus the objects seen through the colored glass seem to be of the color of glass. In the case of all the separate colors we find that they possess three characteristics:

1. They have a definite tone due to the number of the vibrations per second.

2. They possess a definite intensity, due to the degree of the vibrations. It is thus that we have the variation in the color sensations from a bright to a dark color.

3. They are all definitely saturated depending upon the amount of white in the color. There is perfect saturation when all white is absent as in the case of the primitive colors of the spectrum. We have different theories of color perception. Young and Helmholtz have given an ingenious theory of the perception of the different colors. Their theory presupposes that there are in the retina three sets of nerve fibres, one set acted on strongly by the red waves, another set by the green and a third by the violet waves. Each cone is said to be connected with three of such nerve fibres. The red, green and violet are supposed to be the primary sensations.

If the light is homogenous all of these sensations are excited but the intensity of the sensation depends upon the length of the wave. The longer waves arouse the red fibres, moderate waves the green, and the short waves the violet, the other fibres being in each case feebly excited so that the sensations are respectively red, green and violet. When both red and green fibres are strongly stimulated a sensation of yellow color is produced. A strong stimulation of green and violet fibres leads to the sensation of blue color. When all the three kinds of the retinal nerve elements are equally stimulated a sensation of white light follows. Thus the yellow, blue and white are modified color sensations depending upon the blending of the primary color sensations. This theory seems to explain:

1. Daltanism or color-blindness for we may imagine a person who cannot apprered color as one in whom the red retinal nerve elements are either absent or paralyzed. All eyes have some form of color sensation although the sensation for special colors may be absent. Color blindness exists to a great extent, the most common color in which sensation is absent being red.

2. This theory also accounts for the fact that negative retinal images are always of the color that is complimentary to the color of the object looked at. Thus, if the eye is fixed intently for some time on a red surface, the red nerve elements become exhausted so that when the eye is turned on to a white surface these elements will not respond to the red rays in the white light. The green and the violet elements will however, respond to the rays of the white light which affects them and so a bluish green appearance will be seen on the white surface. Hering proposes another theory of color perception. He believes that these color perceptions depend upon the different changes of a molecular character taking place in the retina. Hence he says that in the metabolism of the retina we have the anabolic processes associated with blue, green and black representing the constructive processes of vision, while the katabolic processes are associated with white, yellow and red or the destructive processes of vision. Instead of the three pairs of colors being

complimentary as in the Young theory they are opposites. Wundt propounds another theory in which he says that whenever the retina is stimulated by light there is a two-fold process taking place:

1. A chromatic process depending upon the length of the wave and producing a tone in the case of color.

2. An achromatic process depending also upon the length of the wave but being connected with the intensity of the color. In the achromatic stimulation there is a maximum attained in the yellow leveling along the varying spectrum colors. If we look at a small spot on a colored surface, the spot being black or white or gray, the spot seems to be of the complimentary color to the ground. For example, a gray point on a red surface seems to be greenish blue and on a blue surface the same point would be pink. These are presumed to be due rather to the visual judgment than to the visual sensation. In the eye-ball there is a point the center of rotation situated a little behind the center of the antero-posterior axis. Through this center pass the antero-posterior axis also the vertical and transverse axis and around either one of these axes rotation may take place. To the eye-ball there pass six muscles by the contraction of which the rotation of the eyeball around these axes is produced. Thus the eye is turned outwards by the external rectus, inwards by the internal rectus, upwards by the combined action of the superior rectus and inferior oblique, and downwards by the combined action of the inferior rectus and superior oblique. In looking at any object both eyes are fixed upon the one point called the fixed or visual point and a line passing from the center of rotation of the eyeball to the point is called the visual line. By the two visual lines converging an angle is formed.

3. Movements of the eyeball in rotation along the vertical or lateral displacements. This rotary movement is indicated by the angle formed between the transverse and visual planes, this angle being called the angle of rotation. Normally the two eyes move symmetrically so that the visual lines are directed towards the same point in space. Although when looking at any object with both eyes an image is produced on each retina yet there is only one single sensation experienced as long as the images are formed in the corresponding points of the two retinas. The two yellow spots represent respectively the corresponding points. The portion of the left retina to the inside of the yellow spot corresponds with the portion of the right retina to the outside of the right yellow spot and vice versa. If one eyeball is displaced the images are not formed on corresponding points of the retina and double vision results. If the other eye is displaced correspondingly then the vision becomes single as the image falls upon the same point. There are thus corresponding points on the two retinas, the two yellow spots coinciding, the upper and lower parts in each retina corresponding and the interior of the left retina corresponding with the exterior part of the right retina. If an object is viewed from a number of points, the object will be seen singly from all the objective points provided the angles from the points to the two eyes are equal.

A line joining these points representing the objects will represent the haropter

which is the circular line connecting different points in the visula field forming images on the corresponding parts of the retina or the sum of all the points seen single by the two retinas while the point of fixation remains the same. All the points not included in the haropter will represent points at which object will be seen double. If the eye-balls are so fixed or acted on by the muscles as to see objects not of this haroptric line there is a double vision representing the strabismus or squinting condition of the eye, as distinguished from binocular vision. The eye itself normally is a mechanism whose movements are so directed on the principle of convergence as to secure single vision. There is thus not only the power of converging the eye ball so as to focus the rays upon the yellow spot but also the power of accomodating the vision to the object and its distance. The rectus externus and internus here have a function to discharge of special importance in regulating the convergence. If in looking at a distant object the axes are parellel, accommodation is suspended. If however the axes are turned internally there is contraction of the pupil due to contraction of the cilliary muscles. The two eyes rise and fall together, leaving the line of vision in a single plane. Corresponding to the retinal points in the blending of images are the brain centers at the terminals of the optic nerves. This implies that there is a consciousness of a single image upon the retinas, even when the two images on the retinas differ there is a psychic power of fusing the two images. When an object is photographed on the two retinas, although the retina represents a plane there is power to produce an image representing all sides of an object in space. Although the pictures on the retinas differ a fusion takes place by means of which a single object is seen.

1. Wheatstone propounded a theory to explain the single object by claiming that when there are different pictures they are reduced to unity by the mind and that in this mental fusion of different pictures we have the basis of distinctions between depth, solidity and relief. In this way the mental perception and judgment becomes the basis of space conceptions. The objection to this theory is that the mind does not fuse these retinal pictures but the mental operation has to do with ideas based upon comparison of objects of pictures or pictures.

2. Brucke's Theory. According to this theory both eyes are constantly in motion, the convergence taking place from side to side so that the object is viewed on all sides thus giving rise to the sensation of depth, solidity and relief in space. This means that when nervous impressions arise in connection with the muscle of the eye-balls then there results a perception of the qualities of objects in space. It has been pointed out that even where there is a sudden flash of an object too rapid for the production of convergence there is still the sensation of depth, solidity and relief. According to Wheatstone this indicates that the sensation of relief is immediate, although this does not exclude the nervous impulses which take place reflexly however sudden the object may pass and repass before the vision. This fusion of objects that are dissimilar seems to depends upon the physical and mental accommodation which by habit comes to be most perfect, even without distinct consciousness.

The sense perceptions, if they exist for a definite length of time, are referred to external objects. This depends upon habit. In the case of persons who have been blind at birth to whom sight has been restored there is not the same sense of externality in the objects of vision as they are supposed to be nearer the eye. Gradually by a process of training in conjunction with the tactile sensations the sense of vision becomes familiar with external objects and their relations. The image of external objects upon the retina is inverted and yet in sense perception these objects are vertical. Consciousness is concerned not with the image on the retina but with the rays of light that produce this retinal image as these rays of light emanate from some luminous object. Even when different images are thrown upon the retina by the running of the eye over a large object we are unconscious of the varying segmentary pictures produced on the retina and become conscious only of the single object, the movements of co-ordination bringing all the parts of the object in succession upon the central point of rotation. Objects can be localized by their relations to other luminous objects in space placing the eye in a definite position so as to be able to discern those relations. In a dark space, for example, we cannot locate a luminous body unless there is another luminous object with which to compare it. Thus we localize by observing relative positions of objects. If a luminous ray of light fall upon the retina it will be seen as a single line, even though it is placed upon a number of rods or cones, each rod or cone being excited by a single sensation. The same thing is true of a surface whose image is cast upon the retina, the different parts corresponding with the portion upon which the image falls. All the separate images are blended together in the formation of a complex image.

The retina being an arched surface when a long straight line is seen at a distance it appears curved. In regard to distance the eye judges (1) from the size as determined by the angle of visual observation formed by the marginal rays of light falling upon the retina and (2) from the intervening objects between the object viewed at a distance and the eye. In the case of a water surface it is very difficult to estimate the width of water between the eye and a distant object because there are no intervening objects which can form the basis of comparison. That this is the cause can be easily proved by looking at a distant shore with a number of ships intervening between the shore and the eye.

THE SENSE OF TOUCH:—Of the general condition of the parts and tissues of the body other than the skin we only know in a vague and indefinite way. There is only what is called general feeling, a condition however which may under various circumstances pass into a feeling of pain. The sense of touch is associated with the skin. Some nerve fibres terminate in very fine fibrils in the epithelium as for example, in the cornea, in the mucous of the mouth and in the deep epidermis. We find nerve terminations in a single cell or in a group of cells these representing the cells of touch. These cells are of different kinds, the simple cells found in connection with the epidermis; the group of cells or corpuscles representing two or more cells, larger than the simple cell in

connection with which we find touch discs lying between the cells forming the terminals of the nerve fibres; the compound tactile corpuscles found in the papillae of the true skin especially in the palm of the hand and the sole of the foot. Around about these corpuscles we find nerve fibres in spiral forms, the corpuscles being composed of flattened cells. A peculiar kind of these corpuscles as been called end-knobs consisting of a number of cells in the midst of which we find nerve fibres, the whole group of cells being joined together by connective tissue. These corpuscles are found in connection with the conjunctiva and in the mucous of the clitoris. In addition to these we find the end bulbs both of a simple and a compound character, the former consisting of a modified nerve terminal and the latter forming the corpuscle of Pacini being elongated bodies consisting of an external part, an internal knob and an axis cylinder. These Pacinian corpuscles are found in the connective tissue of the sole of the foot and palm of the hand and also in connective tissue of the deep parts of joints. Touch is a sensation associated with pressure in connection with the external surface of the body. Some call it a sensation of simple contact but even in the most delicate contact there is a certain amount of pressure. There is no contact without some slight pressure. The pressure may become greater and in that case there is a feeling of resistance. If the resistance is great it becomes muscular; hence by the muscular sense is meant the indefinite sensation by which the state of the muscles and the amount of concentration necessary to produce any particular movement are determined. Our movements are guided partly at least by the sense of touch and partly by visual and other judgments. If this pressure becomes excessive then they have the feeling of pain. By means of touch we are able to appreciate mechanical stimulation and force. From the skin we may have general sensations, for example, that produced by the passage of an electric current. By the stimulation of the special sense organs we get special sensations of contact, pressure and temperature. What is true of the skin is true also of the various mucous membranes for a short distance from the various orifices that open on the external surface. The intensity of sensitiveness is determined by discovering the shortest distance at which two points of a pair of compasses may be felt. Not only is the skin very sensitive but the exact location of the sensitive sensation can be localized. This localization of sensitiveness depends upon the number of nerve fibres. For example, by comparing the tip of the finger with the back part of the hand. It was at one time supposed that sensitiveness was improved by proper exercise. It has been found however that the continued exercise does not necessarily improve sensitiveness. The sense of absolute sensitiveness depends upon a number of conditions and particularly upon the sense of pressure determining the intensity of the sensation. The localization of the part touched is determined giving us the means of determining the position of the body brought into contact with the object. By touching a body at different points by comparing the different pressures and estimating the various points in space occupied by the body in contact with the object, the shape of the object

may be determined. When the hand or fingers passed over the body brought into contact with the fingers there is formed a number of tactile pictures so that by means of these a perception is formed in regard to the shape and size of the object.

If there is anything abnormal in the development of the body then there may be formed a false conception of the object. The commonly accepted theory of touch is that developed by Weber and Lotz. It is based upon the supposition that although every tactile sensation is referred to a certain part of the tactile field it is to be referred to a circular region of the skin named the circle of sensibility. If two of these circles of sensation overlap each other they cannot be separately preceived. Each of these circles is supplied by a single nerve. The sensation of temperature are also localized in the skin. This rests upon stimulation by heat applied to the terminal organs. By dipping the elbow into ice water, cold is experienced at the elbow and pain is felt at the points of the fingers in which are located the terminals of the ulnar nerves. If any portion of the skin rises above its normal temperature, there is heat felt, vice versa cold is felt. The normal body temperature at any part of the body depends upon the amount of blood that passes through that portion of the body. If the body comes into close contact with a good heat conductor cold sensations are felt because of the removing of heat from the body. If heat is borne to the body by a good heat conductor then the temperature is raised. All parts of the surface are not equally sensative to the pressure and temperature. Thus the palmer aspect of the fingers appreciate pressure much more delicately than the surface of the arm. The parts of the skin most sensative to temperature are the cheeks, the eyelids etc. It would seems that the appreciation of pressure is heightened by contact for if the finger is dipped into murcury the pressure is felt especially at a ring, at the surface of the fluid. Two points near together in contact with the skin are felt as one point but the distance between the points necessary to produce this result varies widely in different situations. On the tip of the finger or of the tongue the two points must be very near together to be felt as a single points while on the trunk a considerable distance may separate the two points yet the person supposes that only one is touching him. It has been suggested that the temperature acts on a nerve fiber terminating in the corpuscles of the epidermis, that contact stimulates the nerve fibers of the touch corpuscles and that through the Pacinian bodies rude pressure is appreciated. When the skin temperature varies from 20° to 35° C. the tip of the fingers can appreciate a varying temperature of from 20° C. to 40° C. There is a variation in the sense of temperature in the different parts of body. the tongue tip, eyelids, cheeks, lips. Heat and cold sensations vary in alternation. If the body is dipped into water of from 8° to 10° cold is felt. If afterwards it is dipped into 15° or 18° C. then there is feeling of warmth. succeeded by a cold sensation. It is said by recent experimenters that along the surface of the skin there are small regions which are more sensative to cold and heat than others. These regions are said to be associated with the hair of the body. Among these have been localized cold spots and warm spots, the cold spots being more numerous than the warm

spots. The excitation of these points produces the sensations of cold and heat but not of pressure. There is no terminal organs for the sensation of temperature. Associated with the skin we find not only the touch and temperature sensations but also the pain sensations. Pain is produced not by stimulations of the terminal organs or any particular organs but by stimulation of any of the sensory fibers. These impulses of pain pass through sensory fiber and along the spinal cord to the brain. Then the irritation of a sensory fiber may produce pain and if the irritation is so strong as to destroy the normal function of the nerve there is painful sensation. It is not possible always to localize pains. This may be due to the principle of irritation among the different nerve centers, the pains being often felt in regions entirely different from the localization of these sensations. The intensity of pain is dependant upon the intensity of the irritation of the sensory fibers, while the amplitude of the pain depends upon the number of nerve fibers affected, the quality of the pain determined by the kind of irritation and the part affected as well as the extent and continuance of the pressure. Burning, pressing, bitting or any of these acute sensations represent pain or the excessive stimulation of certain sensory regions.

THE SENSE OF HEARING:—The ear is an apparatus constructed for the purpose of allowing sound to stimulate the fibres of the auditory nerve. It consists of the external ear consisting of the concha and the external auditory canal; the mid ear, a cavity that is filled with air connected by the Eustachian tube with the throat; and of the internal ear, a complex structure that is filled with fluid consisting of the vestibule, semi-circular canals and cochlea. The essential part of the apparatus is the internal ear consisting of three parts, the three semi-circular canals and the cochlea connected together by the vestibule. Associated with these we find the specially modified cells at the at the termination of the fibres of the auditory nerve. The stiff cilia-like processes of these cells project into the perilymph and when the fluid is thrown into vibration the processes of these cells are mechanically stimulated and the auditory nerve transmits the nervous impulse to the brain. The external and middle ears discharge the function of collecting and modifying the sound waves. Sound is produced by the vibrations of elastic bodies and transmitted through an elastic media, usually the air. These vibrations consist of oscillations. If these vibrations are imparted to the ear with proper rapidity the result produced is a sound sensation. Sound travels much faster in water than in the air and still more rapidly along any solid capable of vibration. As the vibration passes along a medium the different parts of the medium pass through the same modifications the wave passing along all the different parts. The distance between two points in a vibrating body is called the wave length and it is constant for the same time in a definite medium if the vibrations are equal in number. There are two classes of sounds—noises and musical sounds. If the vibrations of an elastic body are periodic, that is, if every vibration is separated from the preceding and succeeding one by the same interval of time the resulting sound is a musica tone. Non-periodic vibrations produce

non-musical notes or noises. The pitch of a sound depends upon the wave length, the shorter the wave, that is the greater the number produced in a given unit of time, the higher the pitch and vice versa. The intensity of a sound depends upon the amplitude or height of the waves. The greater the amplitude the lower the sound is. The timbre quality or klang of a sound is the peculiar character by which we are able to recognize it as produced in a particular manner, for example, by the human voice, a piano, violin, etc. It depends upon the complexity of the waves and upon the union with the fundamental or keynote of the upper notes. Hearing is a sensation produced by the stimulation of the auditory nerves under the influence of vibrations of sounding bodies. In the external ear we find the auricle and the canal at the end of which we find the drumhead. The auricle of the human ear is irregularly shaped. If these irregular surfaces are filled up with wax or other soft substance the sounds are not distinctly heard on account of the weakening of the sound. When the waves fall upon the auricle some of them are reflected outwards and others are reflected inwards towards the auditory canal. Along the canal the vibrations are transmitted by the walls and also by the passage of air. Even if the auricle is absent there is not necessarily any loss of hearing, the waves being passed along the canal to the membrana tympani. The middle ear communicates with the pharynx by the Eustachian tubes constituting an air passage between the pharynx and tympanum being closed during rest and open during deglutition.

The air pressure in the tympanum is preserved in a condition of equilibrium with the external air which acts on the external part of the tympanic membrane so that it is made entirely independent of changes in the pressure of the atmosphere. If a forcible expiration admits air which is driven forcibly into the tympanum producing a cracking sound in the ear. Similarly a forced inspiration draws air from the tympanum producing temporary occlusion. If the occlusion becomes permanent deafness results. The tympanic membrane is made to vibrate when a sound of an audible nature and of a definite pitch is produced. The tympanic membrane is fixed to the manubrium the result being that resistance is offered to the vibrations of the membrane lessening the intensity of the vibrations and causing the membrane to cease vibrating when the external vibration ceases. The membrane tension varies according to the varying pressure upon the two membrane surfaces and by the contraction of the tensor tympani muscle. When the muscle relaxes the membrane assumes its normal position. This constitutes the power of varying the membrane tension for the purpose of receiving sounds varying in pitch, as the difference in tension makes it more easy to respond more readily and if relaxed low sounds will respond more readily. The special form of the membrane in the arrangement of the radiating fibers makes provision for the convexity of the membrane toward the tympanum while the bands of fibers are convex toward the external auditory canal. This increases the force of the vibrations. The vibrations of the membrane are communicated to the internal ear by the ear and by the

arrangement of the bones the malleus, incus and stapes, forming a lever, the incus being the fulcrum, the power being in the malleus and the resistance in the stapes. This tends to lessen the extent of the vibrations while increasing the force. In the transmission of vibrations from the membrane to the internal fluid of the ear this chain of bones vibrates. The sound wave exerts pressure upon the tympanum the drumhead moving inward and the malleus is borne inward with it, at least the handle while the head moves outward along with the incus the long process of which presses inward. By this movement the stapes is pushed into the oval cavity. The connection of the malleus and incus is such that when the head of the malleus moves the incus is taken along with it. The drumhead is peculiar. The funnel shape of it and its structure of smaller membranes permits of its action in parts the tension varying, being greatest at the middle and less at the sides. It can thus transmit several tones. As soon as the external vibration ceases it ceases to respond because of its rigidity and its close and solid connection with bones. The bones of the head act as conductors of sounds to the ear. If a watch is placed between the teeth its sounds can be heard distinctly even if the ears are stopped, although the sound is not heard for such a length of time. The sound vibrations may reach the perilymph in the internal ear either by the bones of the labyrinth or by the air in the tympanic cavity or by the base of the stapes placed in the oval cavity. In normal hearing the vibrations are transmitted by the chain of bones. The membrane is small being only about 1-10 of an inch in diameter at its widest so that the vibrations must be transmitted by impulses varying in character, the complex character or which is unknown.

Sonorous vibrations must in order to produce a sensation of sound reach and stimulate the terminations of the auditory nerve on the internal ear. They may reach the internal ear through the bones of the skull as when a tuning fork is placed in contact with the head, but as a rule the sound wave: travel through the air and reach the internal ear after passing through the middle and external ears. The sonorous vibrations are collected therefore in the pinna pass down the external auditory meatus and strike against the tympanic membrane in the oval window. This is thrown into vibration and the vibrations are communicated to the air in the middle ear by which they are conveyed to the secondary tympanic membrane. Of much more importance is the fact that the tympanic membrane by its oscillations causes the bridge of ossicles to be thrown into vibration. The oscillations of the tympanic membrane are communicated to the malleus from which they pass to the incus and thence to the stapes. The bones of the stapes are thus alternately driven inward and outward striking against and setting up waves in the perilymph of the internal ear. Through this the waves reach the membranous labyrinth, auricle, and semicircular canals, striking the endolymph and stimulating the hairs of the columnar cells in connection with the fibers of the auditory nerve. The vibrations of the perilymph also pass forward along the scala vestibuli through the helicatrema down the scala tympana as far as the secondary tympanic membrane in the fenes-

tra rotunda. As the vibration pass along the two scalæ they are communicated to the endolymph in the membranous cochlea and so to the hair cells of the organs of Corti. Through these again fibers of the auditory nerve are stimulated. The internal ear has little or no physiological function beyond the mere transmission of the sound waves. The bridge of ossicles has the function of conducting the vibrations of the tympanic membrane to the external ear. We have seen that in doing so it acts as a lever diminishing the extent of the vibrations in the proportion of 3 to 2 but increasing their force as 2 to 3. Further the attachment of the handle of the malleus to the tympanic membrane prevents the latter continuing to vibrate after the waves of sound have ceased to fall upon it. The tensor tympanic muscle by its contraction pulls inward the handle of the malleus and so makes more tense the tympanic membrane. Hence by varying conditions of the tensor tymani muscle the membrane is accommodated for sounds of varying pitch.

The stapedius muscle tends to draw the head of the stapes backward by its contraction and so to partially separate the stapes from contact with the long process of the incus. At the same time it will hold fast or fix the stapes or at least diminish the range of movement. Thus by its action the stapedius muscle will save the delicate structure in the internal ear from vibrations of so excessive a degree that they might be injured by them. The Eustachian tube admits air into the middle ear and through its agency the pressure on the two sides of the tympanic membrane is kept uniform. If this were not the case difficulty of hearing would be caused. Nothing certain is known of the functions of the different parts of the internal ear. It is generally stated that the semi-circular canals have to do with the judgment of the direction from which sounds proceed. Formerly it was thought that the rods of Corti were associated closely with the appreciation of the pitch sound, each note having a particular rod or rods which it threw into vibration. This is not the case because the rods are non-vibratile structures. It has been suggested that the basilar membrane is as it were strung up to different degrees of tension at different levels and that any particular sound causes the vibration of that particular part of the basilar membrane which is tuned to that sound. In other words different parts of the basilar membrane respond to sounds of different pitch while perhaps the rods of Corti act as a deafening apparatus to the basilar membrane.

In order to excite the auditory nerve so as to produce a sensation there are three essentials (1) there must be definite amplitude in the vibrations: (2) there must be definite durations in the impulse; and (3) there must be a definite number of impulses within a specific limit in order to have a tone sensation. The limit between the maximum and the minimum has been placed at 30,000 and 30 vibrations per second. Above or below these limits sounds are not detected by the ears. In the case of the highest audible sound Konighas has shown that the wave length is about 10 mm. In the case of a simple tone we find it depends upon variation in pressure of the atmosphere close to the ear. The air vibrations may be either simply harminic or

they may be in elliptical orbits produced by the combination of two simple harmonic vibrations. The variations in air pressure close to the ear depend upon the law of harmonic motion which is that the velocity of the air and vibrator in the region is infinitesmally small as compared with the velocity of sound. If this law is followed we have simple harmony in tone, if it is not observed and the air passes with great velocity past the margins of the vibrating body then the tones are harsh and deep. It is not definitely known what takes place in connection with the fluid in the labyrinth. Its action is mechanical, the impulses being imparted to minute processes which by their motion produce stimulation of the nerve fibres. There are said to be 300 minute arches in connection with the Corti rods. Each of these arches is supported by the basilaris membrane, forming a base for cells arranged in layers with cilia like processes. The fibres of the cochlear branch of the auditory nerve end in the minute cells associated with the basilar membrane. Helmholtz supposed that the Corti fibres were elastic, all of these fibres being attuned to represent all the possible audible tones. Thus 3000 fibres give 7 octaves with 430 fibres to an octave. According to this theory when a vibration reaches the ear it arouses the fibres which is tuned to its pitch. If there is a compound sound representing different pitch vibrations then the ear may resolve into the simple tones corresponding with the fibre tuning. In this way we are said to have the sensation of pitch. In order to meet the objection the musicians can detect differences of 1-64 of a semitone whereas according to this theory there are but 36 variations to the semitone. Helmholtz stated that if a sound is produced which does not correspond with the pitch of any fiber it will arouse the two fibres between which it lies, the vibration coming nearest to the sound having the greater intensity and so prevailing. Hemsen has confirmed this theory by discovering delicate hair processes in connection with the antennae of the Mysio, these being subjected to vibrations by the use of a key. When certain tones were produced, certain hairs responded indicating the basal fact of Helmholtz theory. Recent histological investigations have raised an objection to this theory in the fact that the Corti rods are not flexible and hence not physiologically capable of vibrating but forming a base for the support of the minute hair cells. Helmholtz suggested that the basilar membrane segments are stretched radially more than longitudinally and in the radial stretching different tension degrees are developed rendering it possible to appreciate different degrees of sound. When these vibrations are brought into connection with the fibres they must be communicated to the brain. As each auditory fibre comes from the cochlea it will be excited by its own hair processes or cells, each fibre bearing impulses corresponding with the intensity of the vibrations. In this way impulses varying in number and character will be carried to the brain cells producing sensations of sounds differing in pitch. Some question the capacity of the ear to appreciate the vibratory phases in cases of two or more tones being sounded together. Helmholtz thinks that the ear only takes account of vibrations without recognizing variations in the form of waves. He thinks that by sounding different

forks at different periods no difference can be noticed in the tone quality. Kelvin maintains that the ear does appreciate difference in phase. By using the sharp and flat topped and the flat and sharp hollowed curves he proved that the ear can distinguish the quality of tones.

Normally the auditory sensations are supposed to refer to the external world, associating the sounds with an external producing cause. This indicates the passage of the sound through the tympanic membrane. If the head is placed in water then the sounds must travel through the body. Hence, it is suggested that the reference of sound sensations to an external origin is due to custom. There is not the same sensibility to all sounds, being more sensitive to acute sounds although the sensitiveness varies in different individuals. This power of appreciating differences in pitch also depends very much upon habit. The fact that we hear with two ears does not affect the auditory sensation. It is probable that the double organ assists in hearing sounds. It has been stated that normally there is a difference in capacity of appreciating sounds in the two ears. This however has not been proved as the two tones of similar intensity at the same distance from both ears are appreciated as a single auditory sensation. It is not easy to discover whether stimulations of corresponding elements in connection with the two ears can be separately distinguished. There is probably the power of distinction if the variation is sufficient to form the basis of such a distinction. It is not only possible to have single sensations but also possible to have simultaneous sensations. In the combinations of sounds, as in music, there is in the ear the capacity of separating the single auditory sensations, at least where the single sensations are distinct enough to be perceived. Concord depends upon the agreeable sensation resulting from the reception of two or more musical tones in the ear, discord representing the disagreeable sensations resulting from the same cause. These depend upon the proportion of the vibrations in the case of two tones.

THE SEMI-CIRCULAR CANALS:—These form a part of the labyrinth and yet their function does not seem to be very clearly associated with the sense of hearing. According to the oldest theory they were associated with the perception of sound direction because the three canals were supposed to represent the three space directions. The three canals represent three planes at right angles or nearly so to each other, being called the horizontal superior and posterior. The horizontal represents nearly the horizontal position in reference to the head being always at right angles to the median plane. The superior and posterior planes form almost equal angles with the median plane. We cannot observe the direction of sound because such a perception can only result from two or more successive observations. It was discovered by Flaurens that if a membranous canal is divided there is produced rotatory motion on the part of the animal around an axis at right angles to the divided plane, the movement taking place in the direction of the divided canal. This led to the theory that the semicircular canals are associated with the co-ordination of movement. Goltz discovered that when the head occupied different positions there would be always a pressure of endolymph upon the canal point representing the lowest part. By

excitation of the nerves corresponding with the different parts pressure would be localized and produce the special sensations which would correspond with the changing attitudes of the head. If this arrangement is interfered with the sense of equilibrium would be lost or impaired. By the investigation of Cyon we have the theory that the semicircular canals give rise to a number of sensations in reference to the attitude of the head, the loss of or the impairment of the sense of equilibrium resulting from the interference with these sensations of equilibrium. Another theory formulated by Crum Brown supposes that the three canals are filled with fluid and that when the head moves in a certain direction the fluid flows in the opposite direction, the flow depending upon the plane around which the movement of the head takes place and also upon the radidity of the head rotation. The fluid in its motion affects the hairs at the dilated extremity of the membranous tube causing a rotatory sensation of the head in the plane of the canal in which the fiuid flows but in the opposite direction. By the continuation of the head rotation the fluid current flow will be stopped even if the head rotation ceases the fluid flow will continue in the same direction as the head rotated producing a sensation of rotation in the opposite direction. There can be a movement between the fiuid and the cavity walls either by the motion of the head, in which case the fiuid is left behind by these walls or else by the stopping of the head motion in which case there is a continuance of the fluid. There is in both cases a rotatory sensation.

According to the theory there is movement both of the fluid and of the walls of the canals and the double labyrinth is regarded as a single organ so that the six canals represent double parallel planes all of which are necessary in order to rotatory sensations. It has been found that by dividing the auditory nerve and causing the rotation of the animal vertigo symptoms are induced. If this is true then there seem to be no real foundation for the last theory. All of the theories therefore seem in a degree to explain the function of the semicircular canals. Equilibrium included the central of the skeletal muscles by nervous connection so that coordination of motion is maintained against gravity. This is one of the most important of body functions. Sensory impressions must be conveyed to the co ordination centers so as to keep close connection between the centers and the different parts of the body. These sensations are called the sense of equilibrium. The muscular sense appreciates muscle tention, the sense of sight appreciates the position of the body in relation to other objects in space, the tactile sensation furnishing the means of appreciating the contiguity of near objects. The air waves act upon the tympanic membrane so that we can appreciate the character of objects that are present. If some of these sensations are lost they may be compensated for by more full development of others but normally all of these senses concur in providing sensory impulses bearing upon equilibrium. If one of these fails or if there is a conflict in the sensations the result is giddiness, nausea, and some other peculiar feeling. Hence by looking at unstable water untrue impressions of the equilibrium are carried to the brain producing the tendency to motions such as to preserve equilibrium.

The sense of equilibrium depends upon the action therefore of various sense organs under the controlling influence of the nervous system. There is however a special organ for the determination of the position of the head and its movement and hence for the regulation of the entire body. The terminal organ has been localized with the semi circular canals. In the case of the lower animals, chiefly birds, it is found that a disturbance of any of these canals produces (1) at rest an exagerated position of the head and (2) as soon as the disturbance is produced there are peculiar movements of the eyes, head and body, the character of these movements depending upon the extent of lesion in the canals. Hence it may vary from unsteadiness to violent motions of the head and body. In the case of man we find that by placing a person on an elevated surface with the muscular and tactile senses inactive and causing movement of the surface the person can determine the motion and its nature as well as the angle of motion. After the sensation of movement there is a sensation of motion in the opposite direction. It has been observed that in deaf persons rapid rotation does not produce giddiness. Where we find pathological conditions interfering with the labyrinth there are vertigo signs in co-ordination. Hence it is presumed that the lesion of the semicircular canals produce a change of pressure in the sensory hair cells by an escape of endo-lymph producing the sensation of falling in one direction, resulting in an attemp to prevent this imaginary contingency.

THE MUSCULAR SENSE:—This refers to the sensation of pressure involving both pressure and resistance to pressure in connection with muscular movements. This may consist of a perception of voluntary activity to perform a definite movement or it may arise from the action of a number of muscles which are in activity. Through the muscular sense the brain centers may receive sensations resulting in information regarding the activity of contraction; the amount of the contraction from which we estimate the character of movements; the rapidity with which the contraction takes place; the time during which contraction lasts and the position occupied by the body and its different members. The sensation of the direction of movements is complicated depending upon visual, muscular and tactile sensations. There is also associated partly with the muscular sense the feeling of equilibrium which is necessary in connection with locomotion whether of the body or the movements of the members of the body. Hence the directions of these movements of motions of the body or its movements depend upon the sensations of pressure resistance and also the visual and tactile sensations. In the case of paralysis as in locomotor ataxia the only guide is the sense of vision directed to the feet and when this is interfered with there is a lack of direction of movement resulting in unsteadiness. By the sensory nerves of the muscles impulses are carried to the brain centers arousing sensations of muscular resistance. Several theories have been propounded to account for this sense: (I) that we estimate the muscular conditions from the efforts necessary to produce a certain contraction, in other words, there is a perception simply of the volition to produce a certain act and not what follows the volition the active effort to propuce the act or motion:

(2) that the muscular sensation arises directly from the irritation of nerves in the surface of skin or membrane that cover the muscles; (3) that there are special muscular sense fibers connected with the muscles which carry the impulses thus originated directly to the brain centers. To compar weights for example, pressure upon skin is not sufficiens; there must be a lifting of the objects, indicating that there is a certain amount of muscle tension and that a deffinite resistance necessary against which the muscle contraction takes place. This seems to indicate that when the muscles contract there is an impulse or a series of impulses passing to the brain indicating the amount of tension and resistance, the nerves in this case being possibly connected with the tendom in which the muscle end, rather than in the muscle itself. Several physiological have localized groups of muscle fiders at the origin of the tendons in connection with the muscles and particularly at the joints.

THE VOICE:—The voice results from the vibrations of the vocal cords, the two bands of elastic tissue of the larynx. We must distinguish this from speech which represents a specialization of vocal sounds to express ideas. We find vocal sounds in some of the lower animals but not the power of speech. It is possible that speech may be found without real sounds as in the signs which are used as a means of communicating ideas. The vocal organ is in the upper part of the neck forming a characteristic prominence. There is an opening above into the pharynx, and below into the trachea. It is composed of a cartilaginous framework united by means of elastic ligaments two of these forming the true vocal cords The arrangement of muscles is such as to move them upon each other so as to regulate the position of the cords. The air is passed through the trachea from the lungs during expiration. The whole arrangement represents a minutely formed sounding apparatus, the lungs forming the wind bag and the trachea the passage for the wind from the bag to the sounding apparatus in the larynx. If two fine elastic ligaments were stretched across the open end of a wide glass tube having a narrow opening between the edges of the ligaments, if by means of a wind bellows a strong current of air is passed through the tube the air pressure would in passing through the ligaments force open the edges, these margins springing back again when the pressure was withdrawn. If there were produced in a rapid succession, then vibrations of the margins would follow sufficiently strong to produce a musical tone or tones. In this case by the condensation of air there is produced sounds. The intensity of the sound would depend upon the variations of the ligaments and the pitch would depend upon the variation in the tension as well as the account and force of the air the larger the amplitude of the vibrations the greater the elastic tension of the ligaments. The cartilages form the laryngeal framework. These cartilages are connected together by means of ligaments, the special mechanism consisting of the inferior thyro-arytehoid ligaments called the trne vocal cords. They consist of delicate elastic fibers with posterior attachment to the anterior projection of the base of the arytehoid cartilages and with anterior attachment to the middle angle of the angle between the laminæ of the thyroid cartilage. They continue the

lateral crico-thyroid ligaments. The ruma glottidis divides the laryngeal cavity into an upper and lower part between the true vocal cords. Above these vocal cords between them and the false vocal cords we find a sac called the ventricle of Morgagni, from each ventricle opening a smaller pouch called the laryngeal pouch extending between the superior vocal cords anteriorly and the thyroid cartilage exteriorly, extending up to the upper margin of the thyroid cartilage beside the epiglottis. The ventricles allow of the free vibration of the true vocal cords. The upper glottidean opening is triangular in shape, the narrow part being posterior and the wide part anterior. It is bounded anteriorly by the epiglottis, posteriorly by the tops of the arytenoid cartilages and latterly by the aryteno-epiglottidean folds. The glottis in connection with the larnygoscope appears as a long narrow fissure on each side bounded by the true vocal cords above which are the false vocal cords, the ventricle opening lying between them. The ruma glottidis in the normal adult male is about 23 mm. from the front backward and 6 to 10 mm. transversely. In females and males before reaching puberty the anterior-posterior diameter is about 16 mm. and the transverse diameter 4 to 5 mm. The muscles brought into play in connection with the vibration of the true vocal cords are the sterno-hyoid and the omo-hyoid, the sterno-thyroid and thyro-hyoid that move the entire larynx and the intrinsic muscles move the cartilages, the crico-thyroid, the posterior crico-arytenoid, and lateral crico-arytenoid, the thyro-arytenoid, the arytenoid and the aryteno-epiglottidean. The crico-thyroid is a short triangular muscle passing from the cricoid to the thyroid cartilages. By contraction of this muscle these two cartilages are brought close together the thyroid being fixed by the intrinsic muscles so that the anterior margin of the cricoid is elevated and its posterior margin being depressed so that the true vocal cords are distended. The thyro-arytenoid has two parts, the external and the internal. Some of the fibers of the anterior part extend from the thyroid cartilage concavely to the vocal process at the base of the arytenoid cartilage so that they form a parallel with the true vocal cords, pulling forward the arytenoids on contraction relaxing the vocal cords. Some fibers also originate from the side of the cord and extend oblixuely to the vocal process. tightening the cord in front and relaxing the cord behind their attachment. Other fibers project the margin of the cord and others produce rotation of the arytenoid The posterior and lateral crico-arytenoids act in opposition to one another. The posterior originates from the posterior part of the cricoid cartilage extending to the base of the arytenoid; the lateral originates from the upper part of the cricoid extending to the base of the arytenoid. The arytenoid cartilages are pyramidal in shape, at the inner angle of the triangular base being the true vocal cords, and at the inner angle the posterior and lateral crico-arytenoid muscles. By the posterior crico-arytenoids there is a rotation of the vocal processes from the inner to the outer and a widening of the ruma glottidis whereas the lateral crico-arytenoids rotate the vocal processes from the outer to the inner and bring the vocal cords together. The intensity of vocal sounds is dependent upon the extent in the movements of the vocal

cords. The pitch is dependent on the number of the vibrations in a given time, the number of vibrations depending upon the length, size and the amount of the tension of the cords. The higher pitch depends upon the greater tension and the lower pitch upon the greater length of the cords. The human voice naturally extends to about three octaves. In the male the cords are larger, producing a lower pitch of greater strength. At the period of puberty there is a rapid growth, the laranyx passing into what is called the change of voice. This change is different in the male and female, being much less in the female. In the female the glottis increases at puberty about one-third in size whereas in the male the increase is about two-thirds. The male laranyx is greater than the female by about one-third. In old age the higher notes become indistinct and gradually weaker, the voice changing in its character as the elasticity is lost, due to ossification of the cartilages, beginning in the thyroid and then extending to the cricoid and arytenoid. The quality of the vocal sounds of the voice are regulated by the same laws that govern the quality of muscular tones in case of an instrument. In a high pitched note the cords are tense, close together and vibrate at their margins only. In producing a low pitched note the cords are more lax, farther apart and vibrate throughout their whole breadth. These different positions and degrees of tension of the cord are produced by contraction of the different muscles of the laranyx. The range of any individual voice is determined by the length of the vocal cords, the longer the cords the lower being the pitch of the voice. Hence in the adult male the vocal cords being longer the voice is deeper than in women and children. The longer an individual makes his vocal cords at any particular moment the higher the pitch of the note produced because here lengthening of the cord means making them more tense. The quality is determined by the various cavities placed above the vocal cords which act as resonators. There are the ventricles of the laranyx, the pharanyx, the nasal fossæ, frontal, sphenoidal and maxillary sinuses. As the entrances to these become smaller or are obliterated in old age the voice loses its fullness and becomes squeaky.

Speech is the production of particular sounds to express certain ideas. The various vowel sounds are produced by varying the shape of the buccal cavity and of the aperture of the mouth through which the air escapes; while consonants are sounded by placing obstacles of different kinds and at different places in the way of the current of air. Thus we speak of labials, dentals and gutturals. The production of voice or phonation therefore depends upon the vocal cords. Musical tones depend upon the vibration of the true vocal cords. These notes are called either pure or mixed notes, being made stronger by the air resonance in connection with the air passages and in the cavities of the pharanyx and the laranyx. In the case of the mixed notes where there is a combination of small or less perfect notes, some of these are strengthened by the resonance of the cavities above the cords. This may be carried to such an extent as to obscure the real note and to produce an entirely different quality of note. Helmloltz has pointed out that certain modifications of

the buccal cavity give to vowel tones a peculiar pitch so that each vowel has its own definite pitch. Thus the quality of the note depends upon two things: (1) the length, elasticity and vibration of the vocal cords and (2) the action of the resonating cavities of the mouth and pharanyx. In vocal music the tune seems to come at times from the throat, from the thoracic cavity and from the head, and notes that are termed falsetto. There is much difference of opinion among musical schools as to the language used in description of these varying registers of sound. The older Italians spoke of three conditions called petto, golo and testa, while the French refer to the head and thorax as the two registers. These variations, however, do not imply any marked phsisological variation in the vocal mechanism. By the use of the laryngoscope the variations in the vocal apparatus can be examined. It is a small mirror about the size of a qnarter attacued to a laıge handle with an angle of 130°. It is put into the back part of the throat so that the light can be thrown udon it, the light being reflected upon the glottis, the reflection being cast back back upon the mirror and then upon the eye. During normal quiet breathing the glottis is shaped like a lance between the cords. By a deep inspiration the glottis is thrown wide open. When there is to be phonation the vocal cords come close together either along their entire length or along the ligamentous part, the space between the arytenoids being open. At the beginning of the sound the glottis is opened, the nature of the opening determinimg the nature of the vocal utterance. While the thoracic sounds are produced the space between the artenoid cartilages is open, the space between the vocal cords being in the form of an elliptical opening, this opening being lessened as the sound increases in pitch. In the production of head voice the opening between the arytenoid cartilages is closed and between the vocal cords is open wide permitting the free passage of air. In falsetto voice the vocal cords vibrate at their margins, chiefly at the middle, vibration at the other parts being prevented by the pressure of the false vocal cords. Some think that in falsetto the vocal cords vibrate in their full length, forming lines parallel to the free margius of vibratiou. Others think that it is produced in the same way as the whistling sound. Voice is thus a modification of sound, the modification taking place in connection with the physiological structure of the vocal apparatus.

Locomotion:—The form and posture of the individual depends largely upon the skeleton structure and the bone union. The human skeleton is a firm and movable frame work of use in determining posture and locomotion. By the union of the bones and muscles there is formed such a frame work as renders locomotion possible. Articulation takes place (1) by means of bony structures, as in the bones of the skull. In the embryonic stage these bones are separate but come to be welded, only a fissure remaining, to indicate the distinction; (2) by means of cartilages. The vertebræ and pelvic bones are united by fibro-cartilages, which permit of movement under the force of grert pressure, returning to their original position after the removal of the pressure; (3) by means of bands of fibers. The carpus tarsus are bound by ligamentous tissues,

these ligaments not only connecting but also giving freedom for slight movements; (4) by means of joints. The surfaces are so arranged as to permit free action, the entering bones being covered with smooth cartilage and the joint portions being supplied with lubricating fluid. There is a close junction of the cartilages at the edges of the joint cavities so that not only is there free action in the case of motion but also a strong connection preventing rupture. The bones are more strongly united by means of ligaments, these ligaments being used to strengthen the joints so that they can be relaxed or tightened according to the movements of the bones. Posture represents the equilibrium of the body which may be kept in one position for a length of time, for example, standing, walking, lying. In order to maintain equilibrium it is necessary that the center of gravity lying side the basis of support. In the adult for example of gravity of the body is about 110 mm. above the middle. In the vertical position the basis of support lies between the feet, varying according to the separation of the feet from one another. In the erect position the feet are separate. the knees are extended, the legs are slightly extended outward, the pelvis extended backwards and the arms extending downwards. The body weight rests upon the feet, which normally rest upon the ground at the heel, little and great toes. When the basis of support is in the single foot the equilibrium is diminished so that if the gravity line is only slightly changed there is danger of falling. In the vertically upright position gravity is secured so as to promote stability. The head is equilibriated on the atlas and the muscles of the back aid in securing the spinal erectness. The center of gravity of the body trunk is posterior to the rotary axis of the femurs, the body being kept straight by the action of the illio-femoral ligaments. The entire body trunk is kept firm upward from the tibio-tarsal articulation. If there is movement at the articulation a tendancy is developed to move the upper parts of the body. Even in a steady erect gait three are slight tendencies to oscillate. In order to accomplish the steadiness of the body there arise a number of slight muscular movements, at one time anterior and at another time posterior, so that body steadiness is maintained. It is in connection with these movements that the muscular sense is developed so that normal sensations arise that lead to the oscillations of the body to preserve equilibrium. Vierordt proved that when sensibility of the soles of the feet become greatest than the erect position is more firm.

The junction of the bones of the rigidity of the trund. The forms of the joints vary considerably, but they are classified as gliding, hinged, saddle, condyloid, ball and socket or pivot joints. In the ball and socket joints there is the greatest varieties of movements, as in the case of the shoulder and hip. The saddle joint has a double axis of rotation as in the case of the trapezius and the first meta-carpal bone. A hinge joint can move only in one plane, the convey surface of one bone fitting into the concave surface of another bone, as in the case of the humorous and ulna. In the sliding joints the articular surfaces are almost flat, the

sliding taking place in various direction although the movement is limited by the ligaments and the capsule. During rest and movement all joint surfaces are in contact, being held in position by means of ligaments or bands of connective tissue. The close apposition of the joints is preserved by air pressure. In the case of the hip joint there is a pressure of air equal to the weight of the skin, bones, muscles associated with the joint so that even although these are all separated the head of the femur will still retain its position. If the air is admitted by means of an artificial opening the joint surfaces will separate and if the air is extracted by a pump they will join again. Thus the air pressure with the muscle tone keep the joints in close approximations. The ligaments are designed (1) either to strengthen and protect the ends of the bones or (2) to prevent movements in an irregular direction, for example, in the ilio-femoral ligaments there is protection on account of the movement of the leg too far outward. In the case of the knee joint there is a simple hinge, there are two lateral ligaments, the semi-lunar cartilages being between the bones. By extending the leg the external ligament is stretched, the internal ligament broadening so that in this extended position the knee cannot be rotated outward. By bending the knee these ligaments become flaccid rendering possible a downward and upward movement.

The action of the muscles is not direct upon the bones but takes place through the tendons. In the case of a narrow tendon the drawing firmer of a broader muscle is fixed upon one point of the bone to be moved so that motion takes place freely. The muscles are adapted to the bones in various ways. The three forms of physical levers are found in connection with the body, the bone moving represents a lever, the articulation in connection with a fixed bone being the fulcrum, the point of insertion of the muscle contracting representing the power and the resistance being determined by the hindrances to the movements of the bones.

1. In the first class of levers the fulcrum is between the power and the resistance. In the extension of the forearm, the elbow joint is the fulcrum, the triceps insertion is the power and the resistance is found in the forearm weight in front of the articulation. In the case of the head balanced upon the vertebral column the articulation between the atlas and the occipital represents the fulcrum, the power is at the insertion of the neck muscles and the resistance is the head weight in front of the articulation.

2. Here the resistance is between the fulcrum and the power. In this lever the arms representing the power is longer and hence its small force may overcome a very great resistance. It is not common in the body. If the body weight is being lifted from the ground by the hands, where the hands rest on the floor would represent the fulcrum. the resistance is at the elbow joint and the power would represent the triceps force. In elevating the body on the tiptoes the fulcrum is where the toes touch the ground. the resistance is the body weight and the power would be the junction of the tendo-achilles and the back bone.

3. Here the power is between the fulcrum and the resistance. This is the common lever in movements of man.

In bending the forearm upon the arm the articulation at the elbow is the fulcrum, the flexor insertion is the power and the weight of the forearm is the resistance. The application of the power is generally near to the body, the arm representing the power, being very short. In this way the movements are rapid and the seemingly clumsy appearance of the limb is rendered unnecessary. The power is most advantageous when it is at right angles to the direction of the lever as in the masticatory muscles and the muscles of the calf of the leg. In other cases the power is pulling slanting and the power can be estimated by the use of the parallelogram of forces. Simple movements such as these seldom take place in the body movement. The movements of one bone in connection with another usually call for the action of a number of muscles which co-operate together in producing the movement. In the movement of the forearm, for example, from a downward to an upward position many muscles are brought into play in the movement in the lower jaw upward the temporal and messeter unite in double movement for the bending of the forearm upon the arm, the biceps and the brachalis-anticus unite in a double movement. Often there is a loss of power on account of the slanting insertion of muscle tendons into bones, when muscles act in antagonism to each other and by the slanting of fibres in different directions even in the same muscle. The slanting attachment is sometimes lessened by the enlargement of the tops of the bones, the protuberances, as well as by the existance of the sesmoid bones in which the direction of the tendon is subjected to change and the presence of pulley like mechanisms as in the case of the superior oblique muscles of the eye ball. The quadriceps extensor, is rendered efficient by the action of the patella in order to prevent the bones of the leg being pulled against the lower part of the femur. By the means of the patella the tendon fibres are pulled forward and atachment is made obliquely to the tibia. In the attachment of muscles and bones of the human body there is a considerable loss of force, although this is in part made up for by the increased motion. Even during rest the muscles are slightly extended so that they have an elastic power in connection with the bones. In this way power is saved because the muscles are in a constant tonic condition of contraction and are fully prepared to act at the slighest stimulus to activity. If one antagonistic of muscles acts there is an effect upon the opposite set as in the case of the flexors and extensors of the arm, thus the latent elasticity is called into play so as to keep up the normal movements of the limbs. The muscle shape has an important bearing upon its activity. The muscles consist of a great number of fibres, representing a series of contractile forces. If the fibres are long as in the sartorius there is a greater number of mechanisms so that there is greater power of extended movements. Muscular power is proportional to the cross-sectional area of the muscles and the amplitude of its movements. The power of movement is usually in proportion to the length of the muscles, but this represents a small power, the larger power being in the thicker muscles with a great number of fibres as in the case of the peroneus longus.

THE ERECT POSTURE:—There is very little muscle exertion necessary to main-

tain the erect posture. It is simply the balancing of the body preserving the center of gravity over the basis of support. In this posture the center of gravity of the head is anterior to the occipito-atlantal articulation, so that the head is free to move forward. The center of gravity of the body including the head is in a line slightly posterior to a line drawn between the hip joint centers, giving the body a tendency to backward movement. The gravity line from the trunk, head and the upper parts of the lower limbs is slightly posterior to the axis of the knee joints and the gravity line of the entire body is slightly anterior to the line joining the knee joints. It is this that makes the body tend to bend the ankle and knee joints. In order to the erect position the muscles must be active otherwise the dead body could stand upon its feet as well as the living body. If a person is required to stand upon the feet for a long time a fatigued feeling results. There are a number of standing attitudes. In the soldier posture the heels are together, the toes being turned outwards, the legs straightened, the pelvis thrown back and the vertebral column straightened. Few muscles are necessary to maintain this posture as the knee extension throws the gravity line a little anterior to the rotatory axis extending the ligaments and stiffening the joint. The backward throwing of the pelvis throws the gravity line a little posterior to the hip joint extending the ilio-femoral ligament. The ankle joint is strengthened by the tension of the muscles in the calf of the leg. Muscular action also balances the head and strengthens the spine. It is not very comfortable on account of the fixation of the muscles. Less fatigue is felt by allowing the muscles to flex somewhat maintaining the body balance by the muscles, particularly if the position is changed frequently so as to change the action of the muscles. The best resting posture is to support the body weight upon one leg, the pelvis being thrown in such a way as to rest the body weight upon the femur. In order to maintain equilibrium afferent impulses must pass to the co-ordinating centers so that efferent impulses may pass to the muscles. If these impulses are suspended as by the closing of the eyes then equilibrium is interfered with. The same thing would be true of the suspension of the sensory impulses from the feet, the joints etc.

LOCOMOTION:—When there is a deviation from the erect posture the body assumes various attitudes, such as walking, running etc. We are indebted to the investigations of Marey and the instruments he has invented for information on this subject. By the use of a shoe with a thick sole in which there is an air chamber communicating by means of a tube with a recording tambour when the foot presses upon the ground there is compression in the air chamber and this is transferred to the tambour. A tambour is also put on the head to record the vibrations of the body so that three tambours record the movements, one for the body and two for the feet. In the case of walking the body never leaves the ground, one or the other of the feet touching the ground while the body is moved forward. Before the walking movement begins the body weight is thrown on one leg, the other leg falling back while the knee and ankle become flexed. Then the body is inclined slight-

ly forward after which the leg that is behind is extended and the body is thrown forward. As the center of gravity is moved forward from the leg that supports the body the movement of the other leg provides a support for the body. As this body weight falls upon the leg moved forward the other leg is freed and then thrown back again. The forward movement of the body is caused by the inclination forward which tends to throw the body forward and also to the pushing action of the leg. Very little work is performed by the body in the act of walking, the swinging movement of the leg being pendular and largely passive. Rapidity in walking is accomplished by the forward inclination of the body and the increased flexure of the legs so as to permit of a greater force pushing the body forward by the movement of the leg, the muscles assisting in the change of the gravity line. By the transference of the body weight from one leg to another there is produces a slight oscillation latterally which produced a swaying motion sideways which is prevented from becoming excessive by the strengthening of the legs in the pendular movement, producing a slight up and down movement. This tendency to oscillate the gravity center laterally is prevented from becoming excessive by the action of the arms, the oscillations upward being prevented by the extension of the moving leg assisting in the support of the pelvis while the other limb is being moved forward. Movement forward of the leg is not a muscular action but depends upon the swinging forward through the arc of a circle of the leg. When the body becomes exhausted then the muscles are called into action. In the case of running there is a greater inclination of the body than in walking, there being a greater flexure of the leg. The body is driven on by a succession of springing movements, at times both feet being removed from the ground, the one leaving the ground before the other reaches it, the rapidity of the running movement depends upon the forward inclination of the body and the strong action of the muscles, the vertical body ocsillations being greater than in the case of walking.

Evolution:—From the stand point of biology there are two important elements that determine and explain the character and activity of the living being. These are heredity and environment. Of these two the most important is heredity. Environment being the changable element that surrounds the individual life. By heredity is meant whatever may be transmitted from ancestor to offspring, whether actual or potential. In environment is included the material such as food, air, water, the natural forces which act as stimuli or constitute the environing conditions of active life. Not only do the principles apply to the origin as a whole but also to the different cells of the organism, although there is a complication in this case arising from the influences by cell upon cell. The action in heredity is internal and of environment external. In the case of the unicellular organism there is the beginning of independent extreme when the parent cell is separated from the child cell so as to form an independent body. In the higher forms of life this implies the conjunction of the spermatozoon and ovum when there takes place the constitution of the germ of a separate life. This forms the period of the inception of life and from this period until

death we find life consisting of the manifestations of certain capacities and powers first imparted to the germ life to which must be added the influences arising from envionment. Biology has been endeavoring to lay emphasis upon these as the two great elements in life and from this stand point they form the essential basis of all vital actions. From the stand points of physiology both of these are of importance. Already we have considered fully the environment element, because the entire connection of life and action alimentation and nervous impulses originating and carrying on the life actions whether internal or external represents the invironments of life. Their presence and influence absolutely control the manifestations of vital phenomena. The physiological account of these living phenomena however would be incomplete without taking account of the second element heredity, particularly around this all modern biological investigation circles. It is true that here we meet largely with theory and opinion rather than fact, but there is a constantly accumulating mass of evidence that seems to render at least plausible the theory of heredity. In biological terms very vital phenomena must depend upon one or two things, either heredity or environment, or upon both of these factors. One thing is self evident there is no spontaneous generation, there is no self originating power. Hence life and its phenomena are derivative. One of the most important evidences is that of resemblance. Histologically and even from the stand point of physiology and physiognomy there is a resemblance between the child and parent including the ancesters of several generations. Their resemblances appear strongest in the direct line of child from parent, diminishing back along the line of ancestry. Francis Galton in his natural inheritance has differentiated the proportion of inheriten resemblance the two direct parents contributing one-fourth each and the four grand parent one-sixteenth each the other one-fourth being inherited from older ancestors. This has been denied by others. It has been pointed out that in addition to individual eccentricities including the physiognomy there have been handed down from the ancestral line peculiar characteristics of race so that whatever species may mean absolutely there is a distinctly marked division in the species in the same genus.

In this case the human race may be one, but this unity is differentiated in groups, such as the Caucasians. These heridity resemblances may be anatomical, physiological or psychological or all of these combined. Anatomical similarities are the most commonly recognized, facial features, color of the hair and of the eyes, and form of the body and abnormalitics, such as monstrosities, vision defects. Physiological similarities include peculiar kinds of locomotive action, characteristic gait, longevity, stoutness or thinness and abnormalities, such as consumptive tendencies. Physiological similaritics depend upon habit; mental characteristics, genius, asthetic and moral qualities and abnormalities, such as a tendency to crime, insanity. In connection with the transmission of hereditary tendencies it is to be noticed that the fact that they do not appear in the individual life does not prove that they are not inherited. It is possible that these characteristics may exist in latency, so that they may be transferred

from one generation to the second succeeding generation without any manifestation in the intermediate generation. Darwin classes the peculiar latency of sex. He says that "in every female all the secondary male characters and in every male all the secondary female characters apparently exist in a latent state, ready to be evolved under certain conditions." According to this a female may inherit the secondary characteristics from her paternal grandmother that have remained in latency in her father, and similarly a male may inherit secondary characteristics of the maternal grandfather that have been in latency in the mother. From a pathological standpoint it is said that hydrocele, peculiarly a male disease, may be inherited in the male from the maternal grandfather though the matter is evident that it must have existed in latency. In such cases the latency involves potential activity with capacity for manifestation where suitable organisms or environments are found.

On this principle we find the individual characteristics reappearing after the lapse of some generations, not manifested in the immediate ancestors. This subject has given rise to some of the most important reseacrhes in the field of comparative biology. Darwin, for example, regards the half cast progeny as reversions toward primitive savagery characteristic of the primitive ancestry of the uncivilized races, the primitive condition remaining in a state of latency. The tendency to revert to these original characteristics is more common before reaching the adult condition of life; when adult life is reached, the tendency being largely overcome by the influence of environments. In connection with heredity we must take account of the fact that there is a possible regeneration of lost parts. Physiologically this is taking place in the body all the time, the wasting and degeneration of parts giving place continually to regeneration of parts in the renewal of the organism. It is however from a pathological standpoint that regeneration is most interesting from the heredity principle. The capacity of regeneration is subject to limitation among the human subjects, but that there is a large field in which it takes place, the re-growth of the epithelial covering of a surface, the regeneration of divided nerve, the union of several bones, the growth of the generated muscle, and the development of the connective tissue furnish examples in the case of man. This regenerative power is much stronger in the lower forms of life, as in the case of the common earth worm, which when cut in two may regenerate from a single half. There seems to be possessed by the existing portions of an organism, if these parts are not deferentiated too much, the power of regenerating the lost portions, this power representing a second embrionic development in many cases.

Much discussion has taken place as to the possibility of transmitting acquired characteristics that have been developed with parent life prior to the independent existence of the off-spring. This is possible in the unicelular organisms, unquestionably for in this case the cellular substance simply divides the off-spring taking the part of the substance as the basis of its independent life. In the case of multicelular organisms it is different, the transmission taking place in this case not in connection with the protoplasm but

through germ cells. Here the question arises as to the relation between the germ plasm and the somatoplasm. Are the changes of the body plasm of such a kind as to evolve similar or analogous changes in the germ cells developed from from the body plasm? Weissmann has classified such changes under three different heads: Those representing lesions, representing functional change and those depending on the environments. Upon the solution of this problem depends very largely issues in the individual and social life. As yet there is no proof that such characteristic changes do pass by inheritance although there is much evidence that poimts in this direction. It is claimed by some that aesthetic tendencies, genius, ambition represent some of these characteristic features transmitted from parent to child. Experiments conducted by Weissmann, for example, cutting off the tails of mice for five successive generations do not change the characteristic of these animals. The forcible compression of the Chinese girl's feet does not render unnecessary the process in every new generation. Brown Sequard artificially caused epilepsy in the case of guinea pigs by operations in connection with the nervous system, the same tendency being transmitted to the off-spring. But this falls short of proving transmission of defects because the system was weakened and resulted simply in the production of the weakened physical system. In this connection much discussion has arisen as to the possibility of transmitting diseased conditions. Deceased body plasm in the parent may produce weakened germ cells which constitutionally represent predisposition to disease and later may develop these ancestral diseases, disease actually attacking the off-spring body. Immunity to disease as well as tendencies to certain diseases may also be transmitted. Much experimentation has taken place in regard to the transmissibility of infection, the result being that infection seems to adhere to families for generations, although here it is probable that the predisposition is what is transmitted. In recent cases it is claimed that the micro-organism producing the diseased condition is actually communicated, of this kind we have two classes:

1. The germinal, in which the micro organism is transmitted in the inception of the germ life.

2. Placental, in which by means of the blood infective germs are transmitted by the circulation. Germinal transmission has been decided by most pathologists at least in the case of tuberculosis. It is admitted, however, that the micro-organisms can be communicated by the circulation in the intra uterine life. Many theories have been put forward to account for and explain the principle of heredity. The modern theories all date from the time when Spencer first published his biological principles. The basis of all theories of heredity is found in the germ plasm. The parent plasm contributes to the new life in the spermatozoon and the ovum, these representing the characteristic qualities of the parent plasm. According to the commonly accepted theory the nuclei of the spermatozoa and the ova, represent the germ life, the body of the ova and the tail of the spermatazoa representing the trophic substance and the active locomotive power respectively of the germ plasma. Hence the essential part of this germ

plasm is the muscles, the transmission taking place in connection with the characteristic of this nucei. There are two theories in regard to the origin of the germinal substance. The Spencerian theory that they are formed in the reproductive organs physiological units, the germ plasm representing all the different parts of the body so that the germ cell represents a minature body organism with all the essential characteristics of the organisms as a whole and in its different parts. The theory of Weissman repudiates the Spencerian theory that the germ plasm is from all parts of the body and says that this germ plasm originates from the parental germ plasm, this germ plasm being back from generation to generation till we come to the original unicellor organisms out of which is developed all of the germ plasms. Thus the germ plasm represents the primitive germ of life transmitted form generation to generation, the body organs being derived from it but these body organisms not contributing to its continuance. As to the nature of the germ plasm we find two theories also. Weissmann believes that structurally it is a complex body; the ovum when fertilized containing within it in germ the future embryonic cells, tissues, etc., the development of which represents the growth of the body from these original cell elements. In this way the ovum consists of various parts, these parts are segments after representing by segment the different parts of the future organism. According to the other theory the fecundated ovum, although consisting of parts, has no essential differentiation of segments, so that the development from these simple parts is largely if not altogether a devlopment under the infiuence of external influences. According to the experiments of Hertwig the separate ovum segments may be developed into a normal but considerably dwarfed organism. According to this theory the ovum segmentation is quantative not qualitated as Weissmann claims. According to these two theories in one case there is organic structure from the first inception whereas in the other case there is no organic structure, the development taking place according to circumstances, representing the two theories of modern times. In the former case inheritance of resemblance is explained by the fact the germ plasm is the same in the line of descent, in the latter case it is explained by the modification of the germ plasm under the influence of environment. It is claimed that resemblance is relative never absolute, there being always a variation in the off-spring from the parent. This resemblance may be germinal in its variation, originating in the germ plasm, or it may be in acquisition after inception, the result of an environmental influences. Hence we have germinal remblance and also germinal variation in resemblance. The germinal variation depends upon the variation in the trophic condition of the germ plasm, the trophic condition being different in different germs. There is always a variation depending upon sexual conditions. The inception of the germ plasm depends upon the conjunction of two individuals so that variations represented in the individuals, as these in turn represent different ancestral lines, produce modification in the germ plasm. Several theories have tried to explain the principle of heredity. The first place is due to the theory of Darwin based upon pangenesis or the theory of the genera-

tion of all living forms from a primordial living matter. Darwin began by stating that the cells of the body indicate by cell division, these cells representing after development the different body tissues and organs. In addition to this he presupposed the separation from its cells of minute granules which are distributed over the able body, these being nourished, developed and again divided, finally forming cell units similar to the original cell units. These minute granules he called gemmules. Separated as they are from all parts of the body, they are collected in the sexual organs, these minute granules having a natural affinity for each other so that as they are separated from the different body units they are collected together to form sexual elements. Hence the reproductive organs are simply glands for the collecting of these organic elements from the different parts of the body, these when collected together forming the basis of the transmission of the body characteristics to future generations. Darwin explains the regeneration of lost parts of the body on this theory by the fact that when the gemmules of this lost part are scattered through the body uniting with the dormant cells at the point of regeneration, these gemmules may remain latent from one generation to another, awakening in the future generation by reversion. By the combination of the paternal and maternal gemmules it accounts for germinal variations, and also by the accumulation of gemmules in connection with these acquired variations being a basis for the transmission of acquisitions. The second place is due to the theory of August Weissmann. According to him, the germ plasm is identified with the characteristic substance of the nucleus of the germ cells. The key note of his theory is "the continuity of germ plasm," according to which a germ plasm of an individual originates from a germ plasm of a parent, the origin being traced backward in direct line of origin of sex. The germ plasm is distinct from the body plasm which represents the entire body organism except the germ. The germ continues the same from one generation to another, whereas the body plasm varies in the individual, being developed from the germ plasm. Thus the body plasm lives and dies, whereas the germ plasm is immortal. In this germ plasm there is definite structure so that each part of the future body plasm is localized in the germ plasm in hereditary units, representing either cells or groups of cells that may vary. These hereditary units consist of smaller units representing the most minute units capable of vital activity. These were called by Weissmann biophars, the hereditary units being called detirments. A group of detirments he called an id, the chromatic substance of the nuclei being called idants. All these units possess vitality and are capable of division in the process of increase. In fecundation there is a union of the idant of the spermatozoon and the idant of the ovum, the result being a combination of material and paternal idants. In this complex combination elements follow two courses, some ids become germ cells from the development of other forms of individual life while other ids make up into detirments, these again dividing into simple units which represent the cells of the organism. This division takes place

largely under the influence of environments so that the environmental influences which potentiality shall become actual in the future developed life. When it has become a body plasm it cannot again return to the germ plasm so that the germ plasm cannot be affected by the body plasm nor can it receive the body plasm characteristics. So that, according to Weissmann, it is impossible to inherit acquired characteristics. Thus the essential principles of Weissmann's theory are two fold:

1. That the germ plasm is not affected by the character of the body plasm, although originating it.

2. That the germ plasm remains the same from generation to generation.

Why, then, we might ask, do we not find all individuals alike? Weissmann says that the germ plasm does not remain absolutely fixed, but is liable to changes arising from trophic variations, these being the initial changes which finally produce individual characteristics. By the accumulations of such variations, with the variations arising from sexual conditions which we find in the production of every individual life, the blending of two separate and distinct beings, we have the basis of individual characteristics. As soon as the variation become definite natural selection comes into play to make more definite this individual characteristic. Where there variations remain latent we find the reversion to antecedent characteristics. In the case of regeneration of lost parts it is assumed that the cells around the lost part have the latent power of regeneration. Oppossed to this theory we find the epigenetic theory, according to which in the fecundated ovum all the parts are alike. Thus the germ plasm consists of of a number of quantitative parts any one of which is sufficient to generate an entire organism, although normally all the parts blend in the production of the organism. According to this theory no predeterminate form exists, the form and function being developed late in the embryonic life, these being determined by the internal reaction of the parts and also by the environment. According to Hertwig the chief differentitation of organ and function taking place in the localization of the different cells, all the cells being alike till the localization produces differenitation. There seems to be an element of truth in in both theories, that there are certain inherent characteristics in the germ plasm sufficient to form a certain predetermination and that this is modified by the environment surrounding the embryonic life.

One important modern theory deserves notice. Schenk has formulated a theory in regard to the influence to the sex production. According to this theory it is clamed that sex production can be controled from the standpoint of nutrition. If this is correct then the trophic influences have an important bearing upon the variations in the individual life. His chief aim is to remóve all sugar from the excretions of the maternal body. His theory is that where sugar traces are found in the mother during the child bearing there is an imperfect body activity, the result so far as the ovum is concerned, being the development of a less perfect organism, resulting in a female child. In order to accomplish this a diet of proteid material, nearly all of the carbohydrate from the food. This dieting according to Schenk must be begun several months be-

fore conception and continued several months after. He admits that he cannot yet entirely control sex production but claims to have established theory to the extent of assisting in the material selection of sex. His chief work has been to examine the excretion of the body with the view of discovering the presence of carbohydrates. He claims that the presence of sugar in these excretions indicates imperfection of some kind in body development.

In the case of the female body he claims that there is a smaller change than in the male body, this being due to less active changes in the blood and also in the alimentary processes. Where the sugar taken in the form of food is eliminated as waste there is an indication of imperfect action of the body mechanism, exhibiting less oxidation power from the process of combustion. Where the activity of the body is less there are less active changes and the result is less strength. For this reason men are physicially stronger than women. Hence where there is imperfect action of the digestive mechanism it is more noticeable in the female because of the less degree of strength. It is of the greatest importance therefore that during the process of child bearing the female strength shall be most perfect, representing the most perfect conditions of body mechanism. Hence if the body is imperfectly nournished and incapable of performing perfectly the digestive functions there is a decided influence upon the ovum. Where the carbohydrates are absent the female organism is stronger and can produce and sustain a stronger and more perfect child. Where the organism is imperfect the ovum is also imperfectly developed. In the former case Schenk thinks there is a male child and in the latter a female child. Primarily the germ plasm does not possess sex characteristics, the sex characteristics depending upon environment, chiefly nutrition, the more fully developed and nourished becoming the male and the less fully developed and nourished the female. In order to control the sex and produce the male Schenk says that the diet must be so regulated as to eliminate every trace of sugar from the waste. This dieting must depend upon the individual case as Schenk admits that in some cases where the dieting was purely proteid a larger proportion of saccharine was found than in the case of dieting on fats and carbohydrates. The normal dieting is the nitrogenous food with fats and only so much carbohydrates as is necessary to keep up body activity without danger of loss to the system. In a list of separated cases, 13 in number, Schenk reports only one failure. The theory is in too formative a stage to be discussed. One objectionable feature in the theory is its depreciation of the female sex. Even if the sex can be controlled by nutritional changes, and such is possible on the basis of environmental changes, it would seem that nothing can be drawn from this to appreciate one sex above another. It has been generally admitted that in the body germ plasm stage there is no sex differentiation, this taking place in the latter embryonic stages. If by regulated dieting this differentiation can be guided it furnishes a proof of the influence of environment upon the development of the germ plasm.

This theory may be criticised from a performative standpoint according to

which every germ plasm represents a complete and perfect organism with all its parts and power latent, so that no power can change its sex. If the performative theory is true then a sexless germ is an impossibillity for the germ plasm must contain all the potentialities of life in a perfect condition. From this standpoint the only possible way of controlling sex would be to prevent inception.

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# Reproduction.

There is not only the power of maintaining an independent existence but also the power of reproducing their kind. Reproduction involves the separation from the parent of a part of its own substance in the formation of an independent organism. It has been claimed that spontaneous generation gives rise to new forms of life without any parent germs of life. There seems however to be no evidence that if the living germs are excluded from either air or water there can be any probably germination of life. There are two methods of reproduction, the asexual which is supposed to be the most primative form, and the sexual which has been developed from the asexual. The asexual method is the chief form of unicellar plant and animal reproduction by budding, fission endogenous cell or spora formation, the most simple forms being by fission. In the amoeba the cell protoplasm divided equally, the separation of the two parts resulting in two independent nucleated organisms. This method of reproduction is found to exist even in bodies where the sexual method referring to the cell multiplication. The growth of an embryo is by asexual development in the cells, these cells being combined together in the formation of a separate individual. In the case of parthenogenesis there may be the reproduction of offspring differing from the parent without any of the sexual elements. In the case of bees the queen bee has fully developed sexual organs, the male being having also sexual organs and the female working bees with imperfectly devoloped organs. During the living process union of the drone and queen takes place, the queen placing an egg in a large comb cell and also placing some spermatic fluid into the small cell. In small cells the eggs are placed within the fluid, in the latter case the males are produced and in the special nutrition of a worker she may become a queen and produce other bees. Among the higher animals reproduction results from the union of the male and female organs. In each sex there are two kinds of cells, the germ cells and the body cells, the former representing nutrition and the latter reproduction. These germ cells are spermatozoa in the male which are small and the ova in the female which are larger and more active. Reproduction consists escentially of the blending of the neuclei of the male and female germ cells. After the sexual union takes place the progress of the newly originated life form is developed by a sexual division, as to the production of sexuality little of this is known. According to some the blending of the cells is for the purpose of renewing the living substance. The asexual power

of the cells become weakened and in order to assist in the process of regeneration the introduction of the new germ plasm takes place. Another view defended by Hertwig is that sexual reproduction hinders variation and assists in maintaining uniformity of race. Hence although the union of different parents produce variation it tends to lessen the variation by production a mean between the differents. Weismann's theory is the opposite of this, that variation is produced, these varieties by natural selection contributing to the production of individual characteristics.

MALE ORGANS:—The essential organs in the male consist of the two testes, complex tubular glands enclosed in a strong covering. This covering from above and behind develops tissue called the mediastinum testes. The accessory organs of the male are the vas deferens, the seminal vesicles, the urethra, the penis, the prostrate glands and the scrotum. The essential functions of these organs is the formation of the spermatazoa and the fluid in which the spermatazoa lives and moves and also connected with the storage and ejectment of the seminal fluid. The spermatazoa represents cells elongated for locomotion. They consist of a head, a central part and a tail about 1-450 part of an inch in thickness. The head is a thin oval body, the central part is a plasmic structure and the tail is a fibrillary plasmic substance. The chief composition of the spermatazoa is nuclein together with proteids, lacithin, cholestrin and fat. It is very active in movement being specially modified in form for fecundation in connection with the ovum. The locomotion is accomplished by the lashing movements of the tail accompanied by rotation at the rate of two to three milimeters per minute. Their production is very rapid and in large numbers, over two hundred million being estimated as produced per week in the normal adult. This excess of production makes it possible for the fecundation to take place in connection with the ovum. These spermatazoa arise in the division of the testicle cells are called the mother cells, these developing the spermatazoa by a process of division. The serum consists of the spermatazoa and the fluid which arises in connection with the testes and the vasadeferentia, seminal vesicles, Cowpers glands and the prostate glands. It is a viscous white fluid with characteristic odor. In addition to water, 82 p. c. it contains solid matters, nuclein, proteids, lacthin, xanthin, cholestrin, fats and the sodium and potassium chlorides, sulphates and phosphates. It is chiefly of value as the vehicle of transmission of the spermatazoa and for their nutrition. The testes cells furnish some of the nutritive matter of the fluid the secretions of the prostatic, the seminal vesicles and the other glands being necessary in order to the mobility of the spermatazoa.

The testes are compound tubular glands appearing in the early embryonic life with small tubules; after puberty the cells begin to divide in the formation of the spermatazoa. As the spermatazoa are formed they pass to the center of the tubules leaving minature cells along the walls. Other cells disintegrate in the formation of the nutritive fluid in minute granules in the fluid. This cell activity goes on during the active secretion of the seminal fluid. The testicle ducts consist of very long tubules, the tubuli recti and rete vasculosum, forming channels for the passage of the fluid. The vas

deferentia and the epididimis canal with smooth muscular tissue and epithelial cilia furnishing a smooth surface for the spermatazoa; the vas deferens with its branching vesicle representing the excretory duct. In the vas deferens there is a storage of the spermatazoa, the glands providing a secretion and the muscular walls assisting in the ejection. The seminal vesicle furnishes the greater part of the fluid secretion. The ejaculatory ducts pass through the prostate glands carrying the semen to the urethra. The prostate gland around the urethra at the bladder's base furnishing prostatic fluid to the semen. The penis forms the channel of conveying the semen to the femal organs, its erectile function being dependant upon the erectile tissues which constitutes the greater part of its structure.

FEMALE ORGANS:—The chief function of these organs is the formation of the female germ cells, its conveyance to the uterus and when fecundated the protection and sustenances of the embryo during its intrauterine life and final delivery at birth. The human ovum represents a rounded cell of protoplasm about 1-125 of an inch in diameter. The nucleus is distinct from the cell body which consists of a very fine framework of protoplasm externally, clear and transparent internally toward the center dense and dark on account of the presence of the dento plasmic substance which furnishes the nutriment of the embryo. The nucleus is spherical and exists away from the center, being limited by the nuclear membrance. The ovum is passive, is fecundated the nucleus being combined with the nucleus of the spermatazoon, the larger part of the ovum representing nutriment. In the maturation of the ovum, the process is analagous to that of the spermatazoa taking place as the ovum leaves the ovary. This takes place by karyokinesis of the nucleus. The nucleus moves outward toward the surface the cytoplasm dividing into two parts, being arranged on either side of the nucleus, the substance between being formed into filament shaped the nucleus being divided into two parts representing two polar bodies that have no special function and the ovum. This involves the reduction of the chromatin substance so as to prepare it for union with the male germ cell, maturation in both cases being a preparation for this union. The ovumis produced in connection with the ovary which is a solid structure, consisting of a frame work of connective tissue with connective tissue cells. The development of the ova takes place in the Graafian follicles. In the human ovary it is estimated that after puberty there are over 70,000 ova, these representing modifications of the germinal epithelial, while the development takes place in the Graafian follicles comes to the ovary surface and rupture takes place in the follicle wall when ready for discharge the ovum being thrown upon the ovary surface to bé taken up by the fallopian tubes. The ovum discharge is called the ovulation. The follicle when emptied becomes the corpus luteum which degenerates unless fecundation follows when it increases before degeneration. Some physiologists suppose that ovulation accompanies mensuration but it does not seem to be limited to the menstrnal period. In the Fallopian tube we find two layers of plain muscle an external longitudinal and internal circu-

lar, the two being lined with cilia, where movements take place toward the uterus. Its chief function is to furnish the channel for the passage of the ova to the uterus and the spermatazoa to the ovary. The uterus receives the ovum and if unfecundated passes into the vagina. It also received from the vagina the spermatazoa and takes them to the ovary. When fecundation has taken place it holds the embryo until the close of the uterine life. It consists of three layers of muscles, the outer and middle coats being thin, the inner layer forming the chief part of the uterine wall. The most important phenomena connected with the female organs is mensturation period. From about 15 to 17 years, representing the age of puberty, to 45 years of age the escape of an ovum from the ovary monthly. Accompanying this are certain changes in the pelvic and uterine organs both of a local and general character. There is an increase in the size of the uterus, mucous membrane being thicker, some parts of the mucous membrane being separated, some the capilaries being ruptured producing a mixed fluid consisting of mucous and blood called the menstral fluid. The discharge may continue for three or four days, usually slight at the beginning and becomes more abundant until it reaches a maximum and then slowly deceases. The amount of blood discharged varies from 100 to 200 grams. The blood arises from the rupture of the blood vessels of the uterine walls. During this period there is a large increase in the blood flow in the uterus. Along with this there is a disintegration of the epithelim the blood being mixed freely with the mucous epithelial cells, red corpuscles, leucocytes. After the flow ceases the mucous membrane is repaired. Accompanying these uterine changes are found a congested condition of the Fallopian tubes and of the ovaries. It is believed that ovulation accompanies the periodic changes. These are also accompanied by signs, usually in the swolen condition of the breasts, the thyroid and carotid glands, the dull and dark skin especially around the eyes. There is often mental and nervous excitement, together with feelings of pair, these changes representing poriodic changes in the entire organism and characterized by monthly rhythm. The begining of menstruation is usually the indication of puberty or the capacity of procreation. In temperate climates it usually occurs at 15 or 16 years, in tropical climates about 3 or 5 years earlier, depending upon the growth and also on the food. In normal conditions it ceases during pregnancy and also during lactation. By the entire removal of the ovary menstruation would cease. The cessation of menstruation indicates the climacteric period of life, usually ranging from 44 to 48 years, the change taking place gradually. Accompanying this change there is also a body change, the reverse of that taking place with puberty. Ovulation and menstruation are largely independant as they do not necessarily coexist. The uterine development prepares for the growth of the embryo. When an ovum is discharged and becomes fecundated it is attached to the uterine wall and a pregnant condition follows. If fecundations does not take place and in connection with the tissue degeneration discharge takes place. Jacobi considers menstruation as the physiological homologue of parturition. It is said to be primarily derived from the

periodic change in condition with the lower forms of life.

Civilization as applied to the human subject has largely modified this original design of nature.

The essential part in the process of reproduction is the blending of the two germ cells. Originally it is believed the spermatazoa and ova are similar cells, being modified during development, the one becoming an active and the other a passive cell. These changes take place in the cytoplasm, the nucleus in both cases being unchanged. The act of coition is the union of the two sexes in the passage of the seminal fluid from the male to the female. The penis becomes rigid and the bulbular organs become turgid. These are produced by vascular dilatation due to the muscular and nervous impulses. Erection is a reflex action, the center being in the lumbar region of the spinal cord aroused by the psychic or tactile impulses, the center acting through the sacral nerves and the hypogastric plexus. From the two first sacral nerves arise the nervi erigentes. Impulses may originate in the brain and from the walls of the testicle duct arising from the pressure of the semen, from sensory stimulation of the penis impulses passing along the sensory nerves to the center. In the female corresponding phenomena are found in connection with the clitoris, the walls of the vagina, the uterus and the Fallopian tubes. The semen is stored in the ducts of the testes, by the contraction of the seminal vesicles the fluid is passed out through the urethra from which it is driven out by muscular contraction of the fibres around the bulbous portion of the urethra. It is mixed with the prostatic fluid and the secretion of Cowper's glands, the prostatic expelling the fluid, final expulsion taking place in connection with the contraction of the cavernosa, constrictor urethra and the anal muscles. In the female there is also a discharge of mucous fluid from the Bartholini glands. Accompanying this there is a downward movement of the uterus and a contraction of the uterine walls. Spermatazoa by quick locomotion make their way into the Fallopian tubes where the union takes place with the ovum. It is generally supposed that the uterine contraction sucks the fluid, which accounts for the os uteri and the cervix. This is aided by the vaginal walls contracting. These movements are assisted by the active movements of the spermatazoa moving along the mucous surface against the ciliary movements which are said to produce spermatazoon activity. The movements are rapid normally as there seems to exist an affinity between the ovum and the spermatazoa, possibly of a mechanical nature. In the maturation of the spermatazoa and the ovum there is a loss of part of the chromosome of the nucleus in each case, after such maturity the fluid being pressed together in the Fallopian tubes, this blending being called fertilization. Surrounding the ovum is the zona radiata of the spermatazoon penetrating the substance of the ovum. The head and central part of the spermatazoon being necessary to the fecundation, are preserved, the tail being unnecessary, is destroyed. The head makes its way to the center of the ovum and by the sucking up of fluid becomes enlarged. The ovum nucleus is found near the center of the ovum where it meets the spermatazoon nucleus, the two

nuclei being fused in the formation of a new nucleus called the first segmentation nucleus. This consists of a chromatic frame work in which is mingled the chroma, the substance, the entire structure being covered with a nuclear membrane. This chromatic substance, half being derived from the sperm and ovum, forms the hereditary substance, this containing all the hereditary qualities of the future individual. As the sperm head is passing through the ovum substance there gathers around it the centrosome, the ovum plasm gathering around the centrosome in the shape of a star, the entire body being called the spermaster. It enlarges and is found in connection with the nucleus of segmentation.

The centrosome is supposed to originate from the central part of the spermatazoon. This spermaster represents the resulting single cell produced by the union of the primary nuclei thus forming the origin of the individual life. The growth of this part represents a complex process of segmentation including cell division, growth, specialization. The early stages of ovum division are technically called segmentation as the human subject being holloblastic. In segmentation there are formed a large number of rounded bodies, the ovum being increased in size. There are three marked acts in each division: (1) there appear two centrosomes instead of one. Each one occupying a position on either side of the nucleus. According to some these two centrosomes represent, one the male and the other the female part of the germ, according to which hereditary qualities are transmitted by the nuclei and the cytoplasm. According to others they arise from the central part of the spermatazoon and are not connected in any way with hereditary transmission, the nucleus alone being the bearer of hereditary characteristics; (2) during the second stage the nucleus is divided, the nuclear membrane disappearing. The achromatic meshwork becomes filamentations arranged from the centrosomes. The chromatic substance becomes arranged in rod-formed chromosomes. The male and female chrosome remain distinct, each chrosome dividing longitudinally. In the nuclear division the male and female elements are equally divided; (3) the cytoplasm becomes divided into two parts, each part taking one of the nuclei, the two blastomere cells taking the place of the single ovum. The blastomeres then divide by karyokenesis and this process of division goes on according to which there are developed a number of similar cells out of which the embryo is formed. By this process of segmentation a large number of rounded bodies called morula are formed. While this is taking place the ovum is passing down the Fallopian tube and goes into the uterus. At the center of the morula some fluid is collected pressing down the cells toward periphery, forming a sac-like structure called the blastodermic vesicle. Here is the embryonic area where the embryo is formed. These cells nearest the blastodermic vesicle form the epiblast, the inner walls forming the hypoblast. The hypoblastic cells increase quickly, constituting a layer lining the epiblast chiefly near to the embryonic spot. The hypoblast cells are small, slightly granular, the epiblast cells being larger and more granular. Around the embryonic spot the epiblast rapidly increase form-

ing an eminence. Out of the epiblast there is developed an intermediate layer of cells called the mesoblast. Out of these three layers all the parts of the embryo are developed. The blastodermic vesicle is enfolded in a cup shape, the edges showing one within another, forming an outer epiblast and an inner hypoblast layer, the cavity representing the original intestine and the opening of the blastopore.

During the segmentation process in the Fallopian tube the uterus goes through a change preparatory to the reception of the ovum, these changes taking place under the influence arising from contact of the ovum with the walls of the tube. The uterus is enlarged, the mucous and the muscular coats becoming thicker. There is an increased blood supply to the walls as well as an increased supply of lymph. The mucous coat becomes soft, a number of large cells being developed called decidual cells, these remaining and not flowing away as in menstruation. When the ovum enters the uterus it becomes attached to the uterine wall, the portion of the mucous coating in which it is embeded is called the decidual serotina. This represents the placenta. The contiguous cells increase and by increasing they surround the ovum with a layer called the decidua reflexa, the rest of the uterine mucous menbrane being called the decidua vera. Laying between the vera and reflexa we find the uterine cavity. The reflexa from being thick becomes thin and approximates to the vera, being completely mergered into the vera after the sixth month. As the embryo grows the vera becomes thinner. The ovum is nourished in connection with the natural tissues. The embryo is encompassed by two foetal membranes, the amniotic and the choriotic or false amniotic. Immediately around the embryo is the amnion very fine and nonvascular. Later it is separated from the embryo although in origin it is closely connected with the embryo. In the amniotic cavity there is the amniotic fluid. This fluid is said to transude from the embryonic and maternal blood, having from two to three p. c. of solid matter consisting of proteids, mucin and salts. It surrounds the whole of the embryo, sometimes passing into the foetal stomach. Its functions are to protect the body, preserve the normal temperature and keep the body moist, also said to be connected with nutrition and excretion on account of the presence of proteids and urea. The chorion is formed at the same time as the amnion and from the same origin. It is thick and very vascular, completely encircling the amnion. Lying between the amnion and chorion is the umbilical cord and the choriomic fluid. As the amnion enlarges the cavity is obliterated. Associated with the chorion are villi on the external surface passing out into the decidual reflexa and serotina. Gradually these villi are obliterated except in connection with the serotina forming a part of the placenta. The allantois develops from the posterior part when fully developed, communicating with the intestine by the urachus. In this we find the allantois fluid with four or five p.c. of solids including allantoin, albumin, urea and salts, representing the embryonic excretion. The blood vessels of the chorion comes from the allantois. They form the two uniting branches of the two umbilical arteries and the one umbilical vein. As development takes place the chorion and

reflexa unite, the reflexa gradually disappearing, the chorion being left frondosum. The deeidua serotine forms the maternal part in the placenta, the foetal part of the chorion frondosum. These two form the placenta. It is a disc shaped mass seven to eight inches in diameter, bound to the internal uterine wall usually on the dorsal side and bound by the umbilical cord to the foetus. The serotina consist of modified layers of mucous membrane, the uterine arteries and vein opening into sinuses. It is not decided whether these sinuses are maternal or foetal. It is generally believed that these sinuses are filled with blood. The chorion sends its villi with the blood vessels into the serotina or that these branches enter the sinuses to be freely bathed with blood contained within them. In this way a close connection is established between the foetus and the mother from circulation and respiration. The maternal blood is conveyed to the sinuses by the arteries and carried off by the uterine veins. The foetal blood under the propelling force of the foetal heart is driven along the umbilical cord in the allantois arteries through the capillaries, returning by the allantoic veins. There is a diffusion in connection with the maternal and foetal blood through the delicate membrane of the capillaries, by means of their absorption the oxygen and nutrient matters being passed from the mother to child and the waste matter from the child being carried through the membrane to the mother. Thus the placenta acts the part of a nutritive and excretive organ in connestion with the embryonic life as it depends upon the maternal life. In this way the embryonic life is retained within the maternal womb throughout the period of gestation. It has been supposed that the uterine glands supply nutriment for the embryo. The embryo undoubtedly absorbs nutriment from the deeidua that surrounds it but this is not sufficient to sustain its life. To provide for this we find the early development of the chorion and the villi becoming a part of the placenta. In order to sustain the embryonic life food is necessary. The food must be in a digested condition in order to be capable of ready absorption. Oxygen must also be supplied but not from lung respiration because the lung is in a collapsed condition. $CO^2$ must be eliminated and this must be done not through the lungs. The excretory organs are as yet inactive. All the interchanges therefore take place in connection with the placenta in the embryonic blood being brought to it including the venous blood that has been directly circulated through arterial system. The maternal blood is also brought into it, charged with oxygen and nutriment. Thus the maternal and foetal blood are brought together, separated by a fine membrane, absorption taking place. The arterialized blood is carried back to the foetal heart and liver and the waste blood of the foetus is carried to the maternal excretory organs. In this way the alimentation of the child is carried on by the mother, absorption carrying the alimentation principles into the foetus so as to prepare for the metabolic processes that are carried on with the foetal body.

In connection with development of the embryo, changes take place in the body of the mother. The entire body is subject to such change but it is in the uterus that the principal change takes place. The cervi uteri becomes enlarged, the

secretion of the glands producing a mucous that closes the cervical passage. The vaginal walls are covered with a serous secretion. The vulvar regions become swollen. Associated with these interchanges are the changes in the mammary glands. These glands consist of a number of acimous glands united by connective tissue to form a gland organ. Associated with the uterine enlargement are abdominal changes often involving abdominal derangements, including the viscera and urinary organs. The amount of nutrition necessary to sustain mother and child increase the amount of work done by the alimentary system, increase in the amount of blood and changes considerably its composition. In the early stages the blood seems to be watery and seems to have fewer red corpuscles, with a smaller amount of hemoglobin. In the later stages the number of red corpuscles and the amount of hemoglobin are increased. The heart's action is increased and the left ventricle is enlarged. The action of the kidneys and of the liver becomes greater. Associated with these is a nervous condition of irritability sometimes involving mental depression and excitement.

In the human subject the period of gestation is about 280 days from the time of fecundation. The beginning of gestation is marked by the union of the spermatazoon and the ovum, but this is often unknown, artificial means are employed to estimate the period. Reckoning is often made trom the time of suspension of the menstruration, calculation being made from the first day of the last mensturation.

PARTURITION:—Some have stated that the stimulating cause of parturition is the fatty degeneration of the decidua. There is also an irritation of the uterine nerves resulting in spasmodic action of the uterine muscle coatings. By the strong contraction of the muscle walls in the uterus the uterine orifice is opened so that the vagina and uterus form one continuous cavity. By partuition is meant the expulsion of the developed embryo along with the attached membranes and the placenta from the mother. It takes place by the contraction of the muscles in the upper part of the uterus and the muscles of the abdoninal walls. The lower portion of the uterus, the cervi, the vagina and vulva are inactive largely in parturition. There is a rupture of the membranes and an escape of the amniotic fluid, followed by an expulsion of the embryo. During parturition there are said to be three characteristic stages:

1. Towards the latter period of pregnancy when the uterine walls are contracted rhythmically. As the first stage of partuition approaches these contractions become frequent and more intense. These contractions are confined to the upper part of the uterus, and peristaltic in their natnre. They are not regularly rhythmical. There is usually a contraction followed by a brief pause before another contraction. Accompanying these contractions is local uterine pain, later being extended to the abdomen and the lower extremities. These are due to stimulation of the sensory nerves of the uterus arising from pressure. As this contraction increases the uterus becomes narrower and elongated, and as this action increases the contents are pressed downwards to the cervix, the embryonic head being presented by a membranous part filled with fiuid, the membrane be-

ing ruptured and the amniotic fluid escaping.

2. Following the escape of the fluid the contractions cease. After a short time they again begin with greater force, being accompanied by the contraction of the abdominal muscles. This results in compression of the abdomen and an increase of pressure in the uterus. Each deep inspiration contracting the abdominal cavity. At this stage the contractions affect the head of the embryo which is found in the cervix. By these contractions it is gradually pushed into the vagina, the rest of the body following. The contractions increase in intensity as also the painful sensations. these being greatly increased when the embryo reaches the vulva. The muscles of the uterus and abdomen are normally sufficient to expel the child.

3. As the expulsion of the child takes place the placenta is separated from the uterine wall, the placenta being connected with the child by means of the umbilical cord. The muscular contraction continues until the placenta is ejected. Associated with this stage there is hemorrhage, due to the surrounding of the passages and the rupture following the separation of the placental attachment. After this the uterus becomes compressed and arrests the hemorrhage. These uterine contractions are partially reflex and partially automatic.

The nerve supply of the uterus comes from the abdominal sympathetics and from the sacral plexus of the spinal cord. There is a reflex center in the lumbar region of the spinal cord. When all nerve connection is cut off these contractions may continue, indicating that there is an automatic muscular contraction of the uterus independent of nerve connection. It is possible that in origin these contractions are muscular, regulated and controlled by nerve impulses.

Changes of Life.—The individual life begins with fecundation, it ends with the death of the body. During the intervening period between these two events there are characteristic changes which are peculiar to the different stages of life, such as the fœtal period, childhood, youth, maturity and old age. There is not, however, any hard and fast line of separation, marking off these stages from one another. Before birth the structure is completed and the functional arrangements developed. At birth the independent existence begins, when all the functions of normal life except reproduction are more or less developed. From birth to maturity these functions are modified. The growth of the body consists of enlargement of the cells, the multiplication of cells and the development of the connective substance. During the embryonic stage the cells multiply; after birth the enlargement of existing cells take place together with the growth of the substance between the cells.

Puberty indicates the period when sexual maturity is reached. It is said to be later in the male than in the female. In the male it is accompanied by body development, maturity of functions, especially of the reproductive organs, one of the most marked changes being that of the voice. In the female it is marked by body changes also, one of the most marked being connected with menstruation, and the uterine changes accompanying it. After a certain period is reached in the male, usually about 60

the life begins to decline, including the reproductive powers. In the female the reproductive power closes about 45 or 47 years of age, representing the climateric. It is chiefly characterized by the cessation of the menstrual flow, accompanied by changes in the entire reproductive organs.

In recent years it has been claimed that decandence begins at birth. As the growth advances the power to grow becomes rapidly less. It becomes, however, more marked after 50 or 60 years, when there is a gradual decline of the powers of vitality. These changes represent degeneration and atrophy. In old age the cell changes are marked, the nucleus becoming small and the cytoplasm increasing in size. For example, in the brain there is a decrease in the weight of the brain, the nucleus becoming smaller and the substance becoming degenerated, accompanied by decrease in brain power. The sense organs become less sensative, the muscles become atrophied and the muscle power lessened. There is a general decrease in the size of the organs, the heart and the kidneys retaining their size more than the other organs. This represents the gradual decline of vitality. Death ensues, representing the cessation of all vital phenomena of the body. Death may be of the organism as a whole or of the individual tissues and organs of which it is composed. The body death takes place when one or more of the functions become deranged, resulting in the breaking down and dissolution of the entire organism. The continuation of a diseased condition of any organs, either from accident of disease, may hinder the restoration of functional symmetry necessary to life. There are many causes of death. It usually results from a failure to action on the part of the heart, the lungs or the brain, or from death of blood. Death originating at the heart is syncope, at the brain coma, at the lungs asphyxia. The muscles live for some time after somatic death but gradually they yield also, losing irritability, the muscles becoming stiff on account of coagulation, called rigor mortis. The stoppage of the heart is gradual, the right auricle being the last to die. After death the muscles and tissues, when the rigor passes away, become soft and flaccid, the body being subject to putrifactive changes which result in its dissolution into the elements out of which it was formed. According to Weissmann the germ plasm representing the hereditary primative plasm is immortal and does not die. It is the somato plasm in which this exists that perishes. The body is thus composed of germ cells and somatic cells, the germ cells being transmitted from parent to child. From this he claims that the original protoplasm was not of necessity doomed to death. Death becomes therefore an acquired characteristic associated with somato plasm. It has become an established principle of nature that the parent die in order that the species may continue to live; each birth representing a partial death in the reproduction of a new organism. The new organism carries the same life from the germ plasm is invariable according to Weissmann.

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